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FOREWORD

WHAT IS disease?

Man is sound as long as all his physiological functions—respiration, digestion, blood circulation, metabolism, and the neuro-psychic processes—are normal. Disease is a disorder of these functions.

This book tells of the new methods applied in the U.S.S.R. to cure many of the disorders that may occur in a living organism; it tells how these methods were discovered, and introduces to the reader the Soviet scientists and practising physicians who discovered them.

These new methods were not hit upon by accident. It was the general progress of science that led up to their discovery.

The investigator treads a tortuous path on his way to a discovery. It takes years of persevering toil to reach the desired goal, years attended by doubts and failures, and even disillusionment. Obstacles arise that often seem insuperable.

Medical history shows that besides difficulties posed by the subject of their research, discoverers often had to bear up against the opposition of other scientists. It was not easy for them to overcome outdated reactionary notions and prejudices; religious prejudices, for example. Take the instance of the discovery of chloroform.

Medicine gave that remarkable anaesthetic to mankind a century ago. But the first surgeons to employ chloroform were fiercely assailed by their colleagues, who feared it would affect their incomes, and narrowly escaped trial for "trespassing upon divine will"; chloroform, you see, made childbirth painless, while "God willed man to be born in pain."

Louis Pasteur had to conquer the scepticism and ridicule of a great many of his contemporary scholars. His arguments and proofs were often bitterly disputed at learned debates, and every setback in his experiments met with a storm of rebuke and derision.

In its day I. I. Mechnikov's phagocytic theory of immunity, which is now a medical truism, aroused bitter controversy. As prominent a microbiologist as Robert Koch, for instance, first thought Mechnikov's views to be erroneous.

Sometimes Soviet researchers also encounter resistance and misunderstanding on the part of individual scientists. But in the U.S.S.R. everything new and progressive never fails to win final recognition.

The Soviet Government spares no means to develop progressive science, science that works to improve man's life, lighten his toil, protect his health and raise his cultural level. In the U.S.S.R. scientists enjoy the solicitous respect of the people, and on this account it is immeasurably easier for Soviet scientists to pursue their research than for their colleagues in capitalist countries. Their road to new discoveries is strewn with fewer rocks.

In the Soviet Union the stimulants and causes of disease are approached from a new angle. Due attention is paid to the environment, and the living conditions.

Tuberculosis is caused by a microbe known as the Koch bacillus. But not every organism invaded by the Koch bacillus falls victim to it. If the person has poor housing, if he lives in a damp, stuffy and overcrowded dwelling, if he is undernourished and his work is dull and exhausting, he is an easy prey to consumption and other diseases. But the danger of contracting tuberculosis shrinks almost to nought if his housing is satisfactory, his diet plentiful, and if he rests normally after a normal working day.

This is also true of other diseases. Lengthy habitation in damp premises devoid of sunlight, for instance, gives rise to diseases of the joints known as rheumatic ailments, and to ailments of the respiratory tracts; exhausting toil and mental frustration cause diseases of the blood vessels and the heart. Disorders of the stomach, the intestines, and the liver, are the result of an irregular diet.

The steady rise of living and cultural standards in the U.S.S.R. promotes successful disease prevention.

The Constitution of the U.S.S.R. ensures the right of citizens to work and rest. A vast network of health-building institutions—spas, sanatoriums and holiday homes—serves millions of working people.

That is why in the Soviet Union disease incidence is dropping from year to year and child mortality, and mortality generally, have shrunk considerably. Epidemics of typhus and relapsing fever, cholera, etc., have become a thing of the past. The number of rickets cases among children is continuously falling, there are fewer cases of tuberculosis, and life expectancy is rising.

* * *

To make a study of morbid phenomena one must be familiar with the vital functions of the sound organism. One must know the laws governing physiological processes.

Darwin's theory of variability and heredity did much to advance biology—the science of living nature. Darwin proved that the changes in an organism are not caused by unknown intrinsic forces, but by the influences of the environment.

Sechenov, the great Russian scientist, stressed that an organism must be studied in close association with the conditions of its existence. He maintained that it was possible to regulate the life and development of an organism by controlling the influences of these conditions. An induced change in environment affects the functions of an organism, fortifying or deranging them at will.

Progressive physicians have long been aware of this dependence of living beings on their environment. Botkin, the noted Russian clinician, defined disease as "a reaction of an organism to harmful external influences." Ostroumov, another prominent physician of the late 19th century, gave an almost identical definition: "Disease is a disorder of the normal life of a person caused by the conditions of his existence in the environment."

Medicine cannot approach any given state of the organism without considering the environment. Physiology and pathology cannot ignore the environment and social factors. The patient's surroundings and living conditions must always be taken into account when framing measures to change the course of his disease.

Great Pavlov was the first to discover how the outer world influenced an organism, and primarily the cerebral hemispheres. The laws he discovered went to make an absolutely new science of the animal organism and its complex relations with the environment. These laws govern the various functions of the brain—the so-called conditioned reflexes, their excitation and inhibition, irradiation, concentration and induction.

Pavlov laid a new, genuinely scientific foundation for modern curative and preventive medicine. He disclosed that in the organism of higher animals and man all processes are subordinated to the central nervous system and that the cerebrum exercises a decisive influence both on normal and deranged functions of the organs and tissues.

This concept of the manner in which a disease originates, develops and subsides, destroyed the previously widespread belief that diseases were isolated, local affections of a given organ. Due to the unifying function of the central nervous system an organism constitutes a single whole, and morbid processes are naturally connected with the vital activity of all organs, and particularly the cerebral hemispheres.

It is principally the favourable effect it has on the central nervous system that makes a method of healing effective. Only this can explain the success of a medical discovery, even, presumably, if its discoverer failed to see, or ignored, the connection between its action and the nerves.

Pavlov's teaching on conditioned reflexes, further developed by his followers, introduced the concept of nervism—of the decisive part played by the nervous system in all normal and pathological functions of an organism.

In some countries the view persists that certain diseases of the parent must necessarily be inherited by the child, and that this cannot be prevented. Similarly, the opinion is widespread that new characters evolved in an organism under the influence of outside factors, are incidental and uninheritable.

This view is based on the delusion that living organisms consist of two entirely different essences—the embryonic cells, or idioplasms, and the body proper, the soma, or trophoplasm. The idioplasm is styled as the seat of "hereditary characters." Characters are inheritable, this theory alleges, if they are embraced by the "hereditary substance," while acquired characters caused by changes in the body, or soma, are uninheritable. The idioplasm, it adds, is insensible to external factors.

This anti-scientific biological trend is associated with the names of such reactionary bourgeois scientists as Mendel, Morgan, and Weismann.

Michurin, the remarkable Russian biologist, scorned these anti-Darwinist views. He showed that living conditions have a bearing on heredity and its manifestations in the world of living organisms—plant and animal alike; he denied the existence of "hereditary substance" and maintained that man could control and reshape heredity. Man could change the hereditary characters of an organism by changing its living conditions.

Timiryazev, Michurin, and Lysenko supplemented Darwin's theory of evolution and natural selection. Michurin biology not only explained natural phenomena, but also showed how to control them.

If an organism develops in habitual circumstances, it differs little from its parents. But in new conditions its development takes a different course, and its heredity changes. By emphasizing one group of factors in the environment and weakening others, and by combining them, it is possible to create new species of plants and animals possessing the desired, predetermined qualities.

The Michurin school has worked wonders. It has produced numerous surprising changes in plant and animal species, and converted winter wheat into spring wheat with a telling and beneficial effect for Soviet economy. Suffice it to say that Michurin raised more than 350 new kinds of fruit-bearing plants.

His followers have raised frost-hardy types and extended the frontiers of vegetable- and fruit-growing to the extreme north. They evolved new highly-productive strains of domestic animals possessing great endurance and yielding large quantities of milk, fat, meat, wool, etc.

The laws of materialist biology apply also to medicine. They offer an entirely new approach to the treatment and prevention of diseases. What is more, they bring us closer to the solution of problems concerning the hereditary transmission of acquired characters.

New horizons open to microbiology. Microbes are known to "adapt" themselves to drugs that previously destroyed them. Streptomycin destroys the meningococci, the cause of fatal inflammations of the cerebral membrane. But if the drug is administered in small doses that are not lethal to meningococci, it finally becomes harmless to them. They "adapt" themselves to it, and eventually it may even become indispensable to their vital activity. Their metabolism undergoes a change under the sustained effect of streptomycin, and their offsprings acquire new characters. The effects of a drug thus produce microbes with new hereditary characters.

Drawing on Michurin's concepts of variability and heredity, medicine can render dangerous microbes absolutely harmless. This is borne out by the work of Soviet microbiologists. They have used live microbes to produce vaccines that are applied with success against diseases in man and animal.

Michurin's ideas chime in with Pavlov's, who has long since adduced the inheritability of acquired characters. Pavlov revealed that vast numbers of conditioned reflexes, or temporary associations, are formed on the basis of inborn reflexes. Conditioned reflexes comprise the sum of habits determining the behaviour of man and animal.

The number of inborn reflexes is by no means constant. New inborn reflexes may appear. Some of the most frequent and lasting conditioned reflexes may turn into unconditioned reflexes. In that case they become acquired characters transmitted from generation to generation. Pavlov wrote: "It may be presumed that some of the conditioned, newly-formed reflexes eventually become unconditioned through heredity." This means that some of the most beneficial conditioned reflexes may finally become permanent, inborn and inheritable.

Pavlov has pioneered research in some of the most important departments of physiology. The crowning achievement of his sixty-year-long endeavour was a new science—the physiology of the cerebral hemispheres, and the materialist teaching on the higher nervous activity. Today Soviet scientists are developing the legacy of the great physiologist to advance theoretical and clinical problems aimed at protecting and lengthening human life.

CHAPTER ONE

AMPOULE OF LIFE

No OTHER TISSUE in the living organism ever aroused so much interest as blood. Blood played a part in religious doctrines and rites, in human relations, and various healing cults. Uncommon properties were attributed to it.

For centuries people thought that blood had a special command over human destiny. In a number of countries, for instance, blood was used to seal oaths and contracts. Blood was made an essential constituent of drugs that were thought to be particularly potent. Although such facts belong to the realm of superstition, they show what sway blood held over men's imaginations.

Even the ancients were aware that this singular, red-coloured fluid tissue played a striking part in all vital processes. Even in the dim past men knew that if the blood left the body, life went with it. Everyone could see for himself what blood meant to life.

It was this that lay behind the deep reverence man had for blood, endowing it with great supernatural powers.

Such beliefs mirrored the tremendous significance of blood for living, and, particularly, for highly-organized living beings.

Science has been sounding the nature of blood to ever greater depths. Blood holds up a mirror to everything that takes place in an organism. It has a part in all the changes that occur in tissues, and in all disorders of the biological functions.

There are diseases, and grave ones at that, which long remain concealed. In their latent stage only a blood test will help to detect them.

Diabetes, for example, often fails to betray itself with any typical symptoms for a lengthy period. Meanwhile, certain phenomena in the blood permit an early and accurate diagnosis.

A great many diseases cannot be diagnosed without a blood test, which also helps to determine how seriously they have affected the patient, and the degree of success achieved in their treatment.

Blood is extremely sensitive to all incipient signs of illness. Its reaction to them is highly important in controlling morbid processes. The facts furnished by blood tests are now utilized in the treatment of well-nigh all sicknesses.

Research has shed light on the highly complex processes taking place in blood. Blood is a compound of a very singular composition. It comprises trillions of cells and heterogeneous substances, each with definite functions. In their absence the organism could not have nourished itself, developed, or resisted disease.

The properties of blood, gradually brought to light, were utilized in the fight for human health.

But there was one important possibility that scientists long failed to grasp. This was blood transfusion.

TWO DEATHS

IN THE PATRIOTIC WAR of 1812 the Battle of Borodino was particularly bitter. Time and again generals marched into the field at the head of their regiments. General Tuchkov was wounded.

Field Marshal Kutuzov sent Dr. Malakhov, his personal physician, to help the wounded general, who had been brought to the field hospital.

Malakhov hastened to the general's side. But when the doctor saw how pale he was, and sounded his pulse and heart, he knew the case was hopeless.

The general's wound was not fatal. But the shrapnel had damaged a major blood vessel—the iliac artery, and caused severe haemorrhage. Tuchkov was dying from loss of blood, not from the wound itself.

Neither Dr. Malakhov, nor any other doctor, could help him. They could stop the bleeding, but it was beyond their power to restore the blood already lost. Death could not be averted. And the general died.

Another example dates back to about the same time.

In the Franco-Austrian battle at Aspern in 1809 Marshal Lannes, Napoleon's favourite, was seriously wounded. A shell shattered both his legs and tore open the blood vessels. Dr. Larrey, senior surgeon of the French army, mounted a horse and galloped to his aid. Lannes still breathed. Larrey dismounted and bent over him.

"Save him, doctor," said the marshal's aide-de-camp. "Use everything science has to offer. That is the wish of the Emperor."

"It is no use," the surgeon replied, rising to his feet. "Science is helpless. The marshal has lost too much blood."

Lannes died.

But the present-day doctor is not as helpless as his 19th-century colleagues.

BLOOD GIVES LIFE

A PROMINENT LENINGRAD architect was walking down the street one day when a sudden pain shot through him. Dark rings swam before his eyes, and the houses about him floated off into the skies. He lost consciousness.

Five minutes later an ambulance brought him to a hospital. The doctor diagnosed acute gastric haemorrhage. Within twenty minutes the architect was on the operating table. His respiration was failing, his heart growing weaker rapidly.

Blood from an artery punctured by an ulcer was flooding the abdominal cavity. Life was at a low ebb.

Man lives as long as his cells, those microscopic bodies that make up the tissues and organs of the organism, and above all the cells ot his cerebral centres. Cells must have nourishment to live, and must excrete waste matter. To assimilate nourishment, they must have oxygen. Without oxygen metabolism, the chemical changes in living cells, is impossible.

Fresh nourishment, and oxygen, are supplied to the cells by the blood. Once this supply fails the deficiency in oxygen deranges metabolism. The cells cease to function. If this happens to the cells of the respiratory brain centre, respiration ceases, and the heart fails if it happens to the cells regulating cardio-vascular activity.

That is why man dies from excessive loss of blood. And that was why the architect was at death's door. But he did not die. He was discharged from hospital three weeks later.

What saved him? The operation? Certainly. The surgeon had opened up the abdominal cavity, located the puncture, removed the ulcer, and sutured the operation wound.

But the operation alone could not have saved the architect. It could not have led to such a rapid recovery if it had not been for the glass ampoule in the nurse's hand. While the surgeon was operating, another doctor pushed the end of a needle into a vein in the patient's arm. A rubber tube connected the needle with the glass ampoule, which contained a dark red fluid. This fluid was blood.

A blood transfusion was made during the operation.

As the level of the fluid in the ampoule dropped, the architect's pallor vanished. His lips took on a rosy hue. He was taking a new lease of life.

This ampoule may well be called "ampoule of life."

It is now plain why General Tuchkov and Marshal Lannes died. They lost much blood and there were no "ampoules of life" to save them.

In their day blood transfusion was unknown.

TWO FUNCTIONS

THE ARCHITECT had a blood transfusion. The most brilliantly executed operation would not have put him back on his feet so quickly without one.

What was more, his life had hung on a thread. He had lost so much blood that the respiratory centre, and the heart, were in danger of paralysis.

But these fatal complications were quickly averted with another man's blood, which carried nourishment and oxygen to the vitally important sections of his body. It also restored the blood pressure in the vessels, which was of extreme functional importance to the cardiovascular mechanism.

Another man's blood took the place of the architect's own.

This function of transfused blood is called substitutive.

But in cases of acute gastro-intestinal haemorrhage transfused blood performs yet another function.

At different times twenty haemorrhage patients were brought to the clinic of Professor Dzhanelidze, of Leningrad. The haemorrhages were caused by ulcerations—gastric or duodenal ulcers in most cases; ulcer of the colon in some. Blood transfusions were made to replenish their blood stocks. After this the doctors waited to see whether their patients would still need an operation to stop the bleeding.

In just one of the twenty cases was an operation necessary. In the others the bleeding stopped, although the ulcers were still there, and, naturally, required further treatment.

Strange as it may seem, in nineteen of twenty cases the blood transfusion stopped the bleeding.

It would appear that the transfused blood added to the pressure on the vessels and dilated them. The damaged wall of the affected vessel would also dilate, and the bleeding would increase. It transpired, however, that transfused blood raised the contractility of the vessels and served to stop the bleeding. This is, presumably, an effect of the stimulating influence of transfused blood not only on the walls of blood vessels, but on the nerve centres governing their contraction.

The ulcerous artery, or vein, contracts as well, provided it is not hindered in this by scars and adhesions. This, in its turn, contracts the puncture and prevents the outflow of blood.

What is more, transfused blood has a high capacity for coagulation. The large proportion of coagulants introduced into the body with transfused blood has a telling effect. A dependable blood clot forms, closing up the puncture.

Yermolenko, a Soviet scientist, has furnished comprehensive proof of this function of transfused blood.

Blood transfusion stops bleeding, but in the architect's case a blood transfusion alone would not have sufficed. He had lost too much blood. The puncture in the artery was very large and the resultant haemorrhage threatened his life. There was no time to lose. He needed both: the operation and the transfusion, and without delay.

Yet his blood loss was much greater than the amount transfused to him. The great loss of blood had weakened his heart. A large supply of blood, introduced in a matter of minutes, would have been too much of a strain for it. The heart could scarcely have coped with it, and would have failed. This explains the small dose of the transfusion.

There are cases, however, when large doses of blood have to be transfused within a short time.

The Sklifosovsky Institute in Moscow found a way of preventing heart failure in such emergencies.

A patient was brought to the institute one day with a big tumour on his kidney. The operation could not wait. Yet he was weak and exhausted by his ailment, and even experienced surgeons thought the case almost hopeless. There would have been a chance of success if the patient had been fortified before the operation, and if his heart activity had been built up a bit. But this would take time, and time was wanting: the swelling was too great.

An extreme measure was taken: six quarts of blood, or more than half a pail, were transfused to the patient. The transfusion lasted six days and six nights. It was what is known as a drip transfusion, made drop by drop. The drip method enables doctors to transfuse a large quantity of blood without jeopardizing the heart.

The six quarts of blood transfused to the patient contained a vast amount of nourishing substances. The heart, meanwhile, was none the worse for it, because the transfusion was slow and gradual.

And the operation, performed on the seventh day, turned out well.

Today the drip method applied by Soviet doctors holds a worthy place in medical science.

SOURCE OF ENERGY

THE MAN WAS WELL, it appeared, but he wandered about the hospital ward pale and listless. And this for many weeks.

He had been treated for enteritis. The inflammation was long since over, but the patient remained weak, tired quickly, and his appetite was poor.

The doctor prescribed a blood transfusion—just a bit over half a glassful. It was not much, but in a few days the patient was a changed man—cheerful and lively.

An ailing chauffeur spent weeks at the skin clinic. He had trophic ulcers of the right arm, so called from the Greek "trophe," meaning nutrition. The ulcers were brought on by disorders in the nutrition of the skin and the muscular tissues.

He had the ulcers for seven years. Diathermic treatment, antiseptic and restorative ointments, and even x-ray treatment, had not helped.

Blood transfusions were tried. First one, then another, and a third—all in small doses. His condition improved, and the ulcers disappeared.

In both these cases the usual reasons for transfusion were missing. Neither patient had lost any blood, or had anaemia. But in spite of that the transfusions had been desirable.

It was not a matter of the blood itself, but of the albuminous substances in its plasma.

Introduced into a foreign organism, albumin acts as a stimulant upon the receptor elements of the nervous system. They generate impulses which the central nervous system transmits to all cells, influencing a change in their vital processes. A kind of reconstruction occurs in the body.

All this gives rise to interesting phenomena.

One man's albumin always differs somewhat from another's both in composition and structure. There are also albuminous colloids. These are extremely sensitive to the foreign albumin in the plasma of transfused blood.

Such foreign albumin attacks the patient's own albuminous particles, as it were, and the cells suffer a kind of molecular shock.

The shock has a beneficial effect. Exhausted and dying albuminous particles fall out of the cells. Expelled into the blood as waste, they reach the kidneys, and are finally excreted.

In this manner the cells rid themselves of old, useless particles, which are soon replaced by new ones. As a result, the processes within the cells gain pace and improve metabolism. That, in its turn, fortifies the patient, improves his condition and raises his spirits.

Academician Bogomolets and his associates have made a close study of these intracellular "storms." Their interpretation of these "storms," or crises is known as the theory of colloidoclastic shock.

After Bogomolets reported his findings to the International Congress on Blood Transfusion his theory was accepted throughout the world as the most plausible explanation of the stimulating reaction to blood transfusions observed in cells.

ANOTHER FUNCTION

THE YOUNG MAN, a photographer by profession, closed the damper of his stove before its time, and turned in.

The smell of coal gas alarmed the neighbours. Sensing disaster, they knocked at the photographer's door, and, receiving no reply, broke it in. The photographer was unconscious, his pulse almost gone. He was poisoned with coal fumes—the carbon monoxide that is a product of the incomplete combustion of coal.

The ambulance rushed the young man to hospital. The doctors bled him, letting out about a glassful of blood, and then transfused two glassfuls of new blood. The photographer regained consciousness and opened his eyes. His condition improved rapidly.

Soviet doctors have recorded numerous instances in which blood transfusions proved effective against poisoning with Berthollet's salt, coal gas, carbolic acid, benzine, snake and tarantula bites, chloroform, and ether.

After passing through the walls of the lungs, coal gas is absorbed by the blood. The immediate task is to render it harmless.

In some cases a blood transfusion dilutes the poison, lowering its potency. In others, the transfused blood ties up a certain amount of the poison and hinders its penetration to other, more important organs. In cases of gas poisoning, for instance, the gas compounds with the haemoglobin of the red blood corpuscles. Tied up in this manner, the haemoglobin fails to absorb oxygen. Death threatens due to a lack of oxygen. Transfused blood, meanwhile, introduces new red corpuscles with normal and free haemoglobin.

The photographer was bled, because some of the coal gas in his system would go with the blood.

The germs of infectious diseases such as typhoid, typhus, dysentery and scarlet fever, produce poisonous substances known as toxins. The toxins are disseminated by the blood, and poison the system.

In the cases of these diseases, therefore, a blood transfusion will have an effect somewhat similar to its effect in cases of poisoning. It may also be beneficial for burns and scalds.

A burn destroys the skin. As the skin decomposes it produces harmful substances. The blood absorbs them. That, in a way, causes acute poisoning, and since it is a matter of poisoning, blood transfusion brings relief.

Let us call this function of transfused blood antitoxic—a function, in other words, which renders poisons harmless.

By virtue of its four functions—substitutive, blood-stopping, stimulating and antitoxic—blood transfusion is desirable in all kinds of morbid conditions.

It was not as easy as it may seem to discover all this. Each gain in the study of the healing power of transfused blood was the result of painstaking research.

Although the miraculous powers of blood have been suspected for many centuries, the practice of blood transfusion is comparatively young. And much persevering effort still lies in store for scientists before so vast a field is fully explored.

RECOURSE TO HISTORY

HIPPOCRATES, THE FAMOUS PHYSICIAN of the ancients, made his mental cases drink human blood. He maintained that the blood of sound persons had a sound soul.

Some 400 years ago a theory was circulated that a man would become brave and generous if he takes blood from one who possesses either of these qualities.

Marie de' Medici, who lived in the early 17th century and was known for her cruelty, dreaded the prospect of old age and its attendant ailments. One of her court physicians suggested that she drink human blood.

At the close of the 15th century Pope Innocent VIII was treated with a potion also prepared from human blood.

Naturally, all these instances only cost the lives of those whose blood was taken for the various potions. But they show that the idea of utilizing the healing powers of blood has occupied men's minds all down the centuries.

The first blood transfusion from man to man was made early in the 19th century. It was made to a patient suffering from stomach cancer—a patient who in that day was doomed to die. Irrepressible vomiting, mounting prostration and emaciation spoke of the rapidly approaching end. André Blondel, the physician who treated him, decided to try a blood transfusion. He had read about its prospects in medical journals, and had even tried it himself on animals. Though the journals condemned the idea as contrary to age-old medical precepts, the physician reasoned that his patient had nothing to lose.

The dying man was transferred to a hospital. One of the attendants agreed to give some of his blood. The transfusion was successful. A day passed, a second, a third, and there were no ill effects. The patient lived.

That was the first blood transfusion in history. It dates back to 1818.

OMINOUS FIGURES

HOW MUCH OF A SUCCESS was this first blood transfusion?

The patient felt much better after it. He gained in strength, and his spirits picked up a bit.

But the cancer was still there, and the improvement was short-lived. The disease was fatal, and the patient soon died.

Yet his case showed that transfusion of blood from man to man was not a mere figment of the imagination. It was perfectly feasible, and gave strength even to a patient who was in a very bad way.

Five years later another blood transfusion was made to a woman near death from acute haemorrhage. It saved her life.

These two, and a few other successes, inspired further research. Transfusions were being tried in various countries. Their number grew from year to year.

But the statistics were discouraging.

By 1869 a total of 57 transfusions was made to patients suffering from severe loss of blood. Sixteen of them ended in death.

Another survey in 1873 reviewed the outcomes of 200 blood transfusions. Of these 76, or almost every second case, were fatal. Death set in from an acute deterioration of the general condition, sudden weakness of the heart, and cramps.

The treatment that was to have saved lives, had instead caused death.

Doctors came to discouraging conclusions. They shrank from transfusions.

The patients who had survived also endured many unpleasant aftermaths—vomiting, fever, heart palpitation, nausea, even unconsciousness. True, there were a few patients who experienced no discomforts whatsoever, but these were the exception.

In Russia a great number of experiments and several dozen transfusions were made in the 40s, 50s, and 60s of the past century. Most of the transfusions, a total of 22, were performed by Kolomnin. Russian doctors likewise recorded many fatalities and complications.

It was all very puzzling. Doctors searched for the root of the evil, and each offered his own explanation.

Some said it was all a matter of blood clots forming after the transfusion. Hence, the blood used in transfusion had first to be defibrinated (fibrin being a blood constituent stimulating coagulation).

Others opposed this view. They put all the blame on the leucocytes, or white blood corpuscles, which disintegrated whenever there was little or no fibrin.

Some thought it was all a matter of the kidneys. Blood transfusions, they asserted, poisoned the urine, and the kidneys were unable to cope with the poison. Others still claimed that the complications were caused by the air which entered the blood stream during a transfusion.

The best surgeons preferred to refrain from blood transfusions. Blood was an enigma, and nobody could find a key to it.

Towards the close of the 19th century the quest for the secret was taken up at many laboratories and clinics all over the world, but it was only in the early 20th century that the solution was finally found.

BLOOD ELEMENTS

WHEN THE ARTERY OR VEIN is punctured blood flows from it in a single-coloured red stream.

But collected in a narrow glass vessel it gradually forms two layers: the upper being light and thin, and the lower—dark and thick. In other words, its solid particles settle to the bottom.

The solid particles, which have a definite structure, are red corpuscles, or erythrocytes, white corpuscles, or leucocytes, and platelets, or thrombocytes.

The fluid layer is plasma. It is yellowish in colour, and, when stirred, liberates fibrous flakes known as fibrin.

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Plasma without fibrin is called serum.

Serum contains nutritive substances, i. e., everything that enters the blood from the intestinal tract, and everything that must be excreted—such waste as carbon dioxide, uric acid and urea, for example; it also contains carbonates, phosphates and chlorides of sodium, calcium and potassium, and other substances.

It is a very complex kind of fluid, as you see.

Blood serum has many properties. And it was the discovery of one of these, that finally solved the enigma of blood transfusion.

SERUM AND ERYTHROCYTES

IF WE WERE TO TAKE THE BLOOD serum of a person who has suffered from, say, typhoid, and add a culture containing typhoid germs, we should soon see the microbes gather in clumps, cease to multiply and, finally, perish. The serum would bring on agglutination, i. e. it would cause the microbes to adhere to each other, and thereby paralyze them. In this condition the human body easily copes with them.

Agglutination was first conclusively studied in the 90s of the last century and aroused considerable interest. Almost all bacteriological laboratories focused their attention on this astonishing phenomenon.

The following experiment was particularly interesting, though it had nothing to do with germs. A drop of one man's blood was introduced into a drop of blood serum taken from another. There appeared clumps of agglutinated erythrocytes.

This was astounding. Erythrocytes, after all, were not microbes, and yet serum agglutinated them. The unusual phenomenon required checking. Erythrocytes from the blood of different persons were introduced into drops of serum. Some of them agglutinated. Two specimens did not. The red cells dispersed in the drop of serum quite normally, without adhering to each other. It was evident that even the blood serum of perfectly sound persons agglutinated erythrocytes. In other words, it was a normal physiological phenomenon, previously unknown. Medical journals printed papers describing it.

An article, entitled "The Agglutinative Properties of Normal Human Blood," by Karl Landsteiner, was particularly interesting. It reported the author's observations of a large number of people. The article turned the tide in blood transfusion.

Twenty-two healthy persons had a blood test; the serum in their blood samples was separated from the erythrocytes; after that the serums and erythrocytes of the different persons were intermixed. The experiment established the fact that the blood of different people has its own properties and distinctive features.

The serum of one healthy person agglutinates the erythrocytes of others. It is as though it cannot tolerate the presence of foreign erythrocytes. This phenomenon may be called blood incompatibility.

But in some of the tests the erythrocytes dispersed quite freely in the serum, formed no clots, and did not agglutinate. The serum seemed to have no objections to their presence. In these tests, we might say, the blood samples were compatible.

It developed at long last that there are three blood types. Blood of the same group is compatible, though it may belong to different people. The blood of people belonging to the same group, when mixed, does not cause the erythrocytes to agglutinate. Furthermore, the erythrocytes of the first, and largest, group may be safely mixed with the blood of persons belonging to any of the other groups. First-group blood is compatible with that of any group.

Persons of the first blood group are thus universal donors.

A person of the second group may receive blood from his own and the first group. The blood of only their own group and, again, that of the first, is compatible with that of persons in the third group. In all other combinations there is bound to be agglutination.

All this was revealed in Landsteiner's article.

Agglutination destroys erythrocytes. After agglutination, the red corpuscles of transfused incompatible blood begin to dissolve—a process known as haemolysis. Clots of agglutinated erythrocytes jam the blood stream while dissolved erythrocytes burden the blood with useless, even harmful, substances, causing vomiting, nausea, unconsciousness, and high temperature. These symptoms are called transfusion complications, and are sometimes fatal.

The secret was solved.

Yet the blood group theory was later amended by Jansky, the Czech scientist. It was found that there were four, instead of three blood groups. The serum of the fourth group does not agglutinate erythrocytes, irrespective of their group. Individuals of the fourth group may receive the blood of any other group, and are called universal recipients.

GOOD START

THE FIRST FEW YEARS after its publication medical men took little notice of Landsteiner's paper. Only police doctors made use of his blood group theory, which was of great help to them in certain instances.

They could, for instance, compare the blood of a corpse with the blood stains found on the clothes of the murder suspect. If the two blood specimens belonged to different groups, it proved that the detained was not the murderer. The blood on his clothes was obviously not the blood of the murdered man.

Some years passed before reports appeared in medical journals suggesting blood tests for both donor and recipient before transfusion, in order to determine whether they belonged to homogenous groups. Only compatible blood, they urged, was to be employed in transfusions. Then there would be no complications, or the complications would be only slight.

Transfusions of compatible blood, these reports concluded, were safe and dependable.

This was a considerable gain. But there remained another hitch. It was a cumbersome and slow operation to suture the vein of the donor to that of the recipient, so that his blood could flow directly to the patient. Moreover, doctors could never know exactly how much blood was being transfused. The method was known as direct transfusion. At the time it was the only method used. Attempts to inject blood taken from the donor and collected in a beaker, ended in complete failure: the blood in the beaker coagulated almost instantly and was useless for transfusion.

A way out was found with the help of sodium citrate, which delayed coagulation. This method of treating blood became known as the citrate method.

A small admixture of sodium citrate preserved the donor's blood, collected in a glass vessel, for a relatively long period without the risk of coagulation.

Direct transfusion became a thing of the past. It was no longer necessary to suture blood vessels. Things became easier and simpler.

In all countries the number of blood transfusions grew by leaps and bounds.

FOREIGN VISITOR

IT WAS IN Petersburg in 1913.

A carriage pulled up at one of the houses in a residential thoroughfare, and a shortish man with greying hair descended from it. His movements were unhurried and dignified.

It was the Austrian Professor Enderlen.

Vyaltseva, a famous singer, was dying of pernicious anaemia in her spacious, lavishly-furnished flat. The best Petersburg doctors, gathered at her bedside, had decided to try a blood transfusion, a new, then barely explored method.

The relatives of the wealthy actress had summoned Enderlen, a transfusion specialist. After examining the patient he sided with the Petersburg doctors and performed a blood transfusion. Two doctors assisted him, and several other prominent physicians came to witness the rare operation. Vyaltseva's husband was the donor.

The operation was performed in the best direct-transfusion manner. The patient's cephalic vein was sutured to the donor's radial artery. Complications set in—the actress lost consciousness, her temperature rose, and the activity of her heart was deranged. Then the ill effects vanished. But the operation proved futile. Vyaltseva died two weeks after it. Her death was not caused by the complications. The patient died because a blood transfusion alone could not cope with pernicious anaemia, which fact was not known at the time. But there were two highly instructive aspects to this episode.

Firstly, Enderlen was a blunderer. He had no idea whether the donor's blood was compatible or not. He failed to test the blood of both donor and recipient, although the advisability of transfusing only compatible blood had already been advocated in print.

Secondly, the invitation of a foreign specialist showed how slavishly Russia's ruling classes of the day worshipped all things foreign, and scorned their own, native science. Yet in the 19th and 20th centuries, and even long before that, progressive Russian scientists substantially contributed to the advance of science. The problem of blood transfusion had not escaped their attention.

As far back as 1832 the Petersburg obstetrician Wolf made a blood transfusion to a woman in childbirth, and in the course of the next decade to four other women.

Filomafitsky, professor of physiology at Moscow University, studied blood transfusion all his life. In 1848 he published a detailed paper describing the history of blood transfusion, and his own experiments. He invented an apparatus for transfusing defibrinated blood.

At about the same time Professor Buyalsky of the Surgical Academy also designed a transfusion apparatus. He maintained with an insight astounding for his day that "blood transfusion is bound to become one of the essential practical aids" of medicine, and not only in cases of internal haemorrhage, as was then generally believed, but also in cases of excessive blood losses attending "surface wounds." And though Buyalsky himself never made a single transfusion, he guessed its tremendous healing power.

In 1867 Rautenberg, another Russian scientist, proposed to counteract blood coagulation with sodium carbonate. And in 1872 Dr. Prozorov made a blood transfusion to save a man poisoned with coal gas. The patient had spent six hours in air contaminated with coal gas, and had been at death's door.

In 1883 Dr. Alexeyevsky reported in the press that he successfully applied transfusions in cases of general poisoning.

Kolomnin, the Russian surgeon whom we have already mentioned, was the first in history to perform a blood transfusion on the battlefield. It was in the Russo-Turkish War of 1878.

Russian scientists, as this brief summary shows, worked with great persistence in the field of transfusion. But under tsarism they were greatly handicapped. The tsarist government showed little interest in education and enlightenment. Ignorance was the best ally of the landlords and bourgeois in exploiting the people and keeping them in a state of submission. The results achieved by Russian scientists were not given sufficient publicity and remained practically unknown, while all things foreign were broadly advertised.

IMPORTANT DATE

IN 1919 A BITTER civil war raged in Soviet Russia. Interventionist armies invaded the country. The young state was passing through a crucial period of its existence.

Factories and plants closed down for lack of raw materials and fuel. Power stations operated irregularly. Communications were paralyzed. The city population received meagre food rations. The lecture halls of universities and colleges were unheated. Professors delivered their lectures in fur coats.

At that time Vladimir Shamov, a young surgeon of the Military Medical Academy, spent all his hours free from medical practice in an unheated laboratory. He took drops of blood from anyone who complied with his persistent requests. He distributed this blood in test tubes and watched the phenomena transpiring in it. Blood groups and compatibility were well known by then. This made possible a broad application of the life-saving method. But progress was impeded by one more problem, which absorbed Dr. Shamov: how best to determine the blood group, how to differentiate the blood specimens and obtain standard samples of all four groups?

The search for the key to the difficult problem was further complicated by the stern conditions of continued civil war. It was not easy to conduct the investigation, not always possible to obtain the required drugs and apparatuses, and, to top it all, the field of research upon which he had ventured was as yet almost unexplored.

But in spite of all these difficulties the problem was solved. Helped by the younger associates of the Military Medical Academy, such as the student Petrov and the intern Yelansky, two enthusiasts like himself, who are today prominent scientists, Shamov finally produced standard blood group samples. It was a signal achievement.

But blood transfusion could not as yet be applied on a large scale. There was a lack of donors. People had an instinctive fear of giving up their blood. They feared that giving away two glassfuls of it, or even just one, would cause prolonged illness, and, possibly, death. Furthermore, food was scarce during the Civil War, people were undernourished and emaciated. Many viewed transfusions as a mysterious and dubious procedure. Under the circumstances nobody was willing to be a donor.

It was at this time that a woman patient in a serious condition was brought to Professor Fyodorov's clinic, where Shamov worked. An operation was imperative, and could not be postponed for long. It was a matter of life and death, but surgeons shrank from it. The patient was emaciated to the extreme, weakened by loss of blood, and was bound to die under the knife.

Shamov felt that a blood transfusion would turn the tide. It would give the woman strength to cope with the operation.

The situation called for speedy action, and Shamov, working against time, searched desperately for a donor. But all in vain.

And then, as sometimes happens, help came from an entirely unexpected quarter. Shamov met a young girl at a friend's house. She was an office-girl, and about to go on long leave. Looking at the robust, healthy, rosy-cheeked girl, Shamov was struck by a happy thought.

What if he were to ask her? Would she refuse? How should he explain that she would save a life and suffer no ill in the doing?

The surgeon pleaded fervently with the girl, whom he did not know. He told her of the patient's desperate condition, and of the transfusion that, were he to find a donor, was the only chance of saving her life, provided the donor's blood was compatible.

The brave girl agreed unhesitatingly.

Shamov made use of his newly-prepared standard samples in performing the necessary blood tests. He was visibly excited as he watched the reaction in the blood drops taken from donor and recipient, and thought the whole procedure terribly slow.

At last his face cleared. The patient's erythrocytes did not agglutinate. The blood of the two women was compatible.

Three days later Shamov made the blood transfusion. In another five days the patient was operated. Her condition had improved so much after the transfusion that the surgeon started upon the operation without any misgivings.

This was the first blood transfusion performed in Russia with an accurate compatibility check.

It was an important medical event.

In 1919, when Shamov made the transfusion, there was not a single blood transfusion institute, or even a station, throughout Soviet Russia.

In 1940 there were a dozen institutes and up to 1,500 blood transfusion stations.

LARGE RESERVES

SODIUM CITRATE checks blood coagulation. This discovery enabled physicians to take the donor's blood and make the transfusion unhurriedly, even three or four hours later.

But it would have been handier still to have blood reserves that kept for three or four days, or weeks, provided the blood remained fit for use. Hospitals could then have a constant stock of blood ready for use at a moment's notice.

Means had to be found to conserve blood. It had become a crying need. Scientists had to find out what happened to blood at various temperatures and under various storage conditions. They had to find out what happened to each of its constituents—plasma, serum, erythrocytes, leucocytes, platelets, and its various chemical ingredients. This was easier said than done.

As transfusion made headway, there appeared talk of trying to conserve blood. But if ever anything was said on the subject, it was merely to express the hope that this could be so. No practical suggestions were made.

And yet some 80 years ago, long before the time of sodium citrate, Sutugin, a surgeon, voiced the idea that blood could be collected and stored for days and yet remain fit for transfusion.

Sutugin did not draw the line on a mere assumption. He made a large number of transfusions of blood taken from the vein seven days previously. They were successful and had no undesirable aftereffects.

These transfusions, naturally, were not made to human beings. They could not have been at the time, for nothing was known about blood groups. The isolated successes of that day did not make up for the large number of fatal outcomes, and Sutugin could not risk the lives of his patients.

He performed his experiments on dogs, and proved that blood stored for seven days possessed the same healing power as freshly-collected blood.

Sutugin conserved the blood by extracting its fibrin content, and keeping it at zero temperature. It was far from being a perfect method, and was bound up with the first steps science was making then in the field of blood transfusion. But the idea itself had come long before its time.

In 1914 blood conservation gained firm ground. Subsequently, Soviet scientists played a big part in advancing it. One of them was Belenky.

He found a way of conserving blood whereby its properties remained unimpaired for four weeks.

The method suggested by Belenky and his assistants is known as the gluco-citrate method. As its name implies, it involves a compound of sodium citrate and a syrupy liquid called glucose.

Balakhovsky, another Soviet researcher, compounded citrate and a certain quantity of physiological saline.

After numerous experiments a group of associates of the Central Institute of Blood Transfusion prepared a special blood-conserving fluid.

Blood may be conserved by a number of methods. Each method has its advantages and disadvantages. The choice of the proper method depends on the circumstances.

The cardinal question today is to find the best method. No wonder Soviet reports on this subject at the International Blood Transfusion Congresses in Paris and Rome provoked so much interest. They described new data. But it was the remarkable papers of Soviet scientists on the transfusion of blood from corpses that attracted the greatest attention.

PROFESSOR'S DECISION

TAKE A LARGE medical institution in a big city; say, some first-aid hospital. Look in at the reception ward. You will see that the doctor there is in great demand. Apart from patients requiring urgent operations, there are victims of traffic accidents and other mishaps.

The doors of the reception ward swing open many times a day, admitting first-aid personnel carrying stretchers. There is still life in the persons lying on them.

Now picture the doctor on duty, the doctors in the wards, their assistants, and the professor who heads this beehive of activity. They scarcely have time to step away from the operating table.

And late at night a man is brought in who accidentally fired off his gun, and injured himself. The bullet penetrated his abdominal cavity.

The professor takes the man's pulse. It is barely perceptible. There are signs of internal haemorrhage. Most likely, a major blood vessel has been damaged, and the blood has flooded the abdominal cavity. An urgent operation is necessary to suture the injured organs and vessels. An immediate blood transfusion must be made at the same time; if this is not done, the case is hopeless.

All the preparations have been completed. The donor has been summoned and is expected at any moment (blood conservation was not known at the time).

But the patient's condition suddenly takes a sharp turn for the worse. The transfusion must be made without further delay. Yet the donor is still on his way.

A daring idea suddenly strikes the professor. A man knocked down by a car has just been brought to the reception ward. He was still alive when he arrived, but died soon afterwards in spite of the fight they put up for his life. The professor decides to take the blood from the dead man and transfuse it to the gunshot victim.

It is all over within an hour: the operation, and the transfusion as well. The patient's pulse grows stronger as the heart pumps the blood taken from the corpse to all the parts of his body.

Certainly, the blood of both the patient and the corpse was tested for compatibility before the transfusion.

All this, but for some minor details, is a true story. It happened at the Moscow Sklifosovsky Institute in 1930.

DEATH AIDS LIFE

THE FOURTH UKRAINIAN Congress of Surgeons took place that same year. Moscow surgeons told the congress of seven transfusions of blood taken from corpses. All seven transfusions had been successful.

This was news to the doctors at the congress. As for the idea of using the blood of corpses for transfusion purposes, that has its own history.

Professor Shamov, the Soviet scientist whose acquaintance we have already made, performed an experiment some three years before the Ukrainian Congress. He let out 90 per cent of a dog's total blood supply. That, in plain words, meant almost all its blood. The dog was dying—its respiration almost gone, its heart beating faintly, its pupils no longer reacting to light. Then it had a transfusion of blood taken from a dog killed ten hours previously. And the dying dog revived, just as though the transfusion was of ordinary blood, and not of a dead dog's.

The Sklifosovsky Institute knew of Shamov's experiments and was the first to apply his method to humans.

But is not death followed by decomposition and decay? Does not the blood disintegrate?

How was it possible, then, to introduce such blood safely into the system of a living being?

But tests proved that the red corpuscles of blood taken from corpses excellently performed their function of oxygen carriers, while its white corpuscles retained their phagocytic mobility and adequately attacked and destroyed foreign particles. Its plasma also remained normal. But this was not all. It had certain advantages over donors' blood.

A corpse yields about three or four quarts of blood, while a living donor cannot even give a full pint at a time. Hence, one corpse substitutes eight or nine donors.

There are still other advantages.

One day a patient was being operated for stomach ulcer at the Sklifosovsky Institute. He was weak and a blood transfusion had to be made during the operation. A quart of blood was transfused to him.

But complications, albeit in a mild form, followed, although the blood taken was compatible. The patient grew pale and had a headache and cramps.

The blood was from different donors. It was compatible blood, to be sure, but apart from erythrocytes and serum, blood contains fibrin, platelets, albumin, lipoids, carbohydrates and numerous other substances whose compatibility even in persons of the same blood group has not been exhaustively studied. There are many secrets to blood that have as yet escaped observation.

Whenever several donors give blood to a single patient there is the chance of sudden ill effects. It is better to take blood from one donor.

But the most a healthy donor can give is half a quart of blood, while a corpse, as we said, can yield up to four.

Blood from a corpse has yet another advantage over that of living donors.

STABILIZERS

During the Great Patriotic War of 1941-45 the need for transfusable blood was tremendous. It was particularly great at the front—at regimental dressing stations, medical battalions, field hospitals, and even in the firing lines.

Every wounded soldier was a soldier who had shed blood. There were many who could only be saved by an immediate transfusion of blood, which was to replace the blood lost from torn, damaged and punctured arteries and veins.

Moreover, wounded men often suffered from a peculiar and dangerous condition arising, among other things, from changes in the blood under the effect of even limited blood losses. It was called shock. The trouble was that a shocked patient could not be operated on, however essential the operation.

Shock was a reaction of the central nervous system to great pain. It could be the effect of a bullet, shrapnel or mine wound, and had all the earmarks of oncoming heart failure from lack of blood. The blood circulated at a snail's pace and seemed to drain away altogether from the major arteries, veins and heart, concentrating in the abdominal cavity, liver and spleen. It was a condition known as circulatory collapse.

The nervous system, disorganized, as it were, by the pain, is to blame for this condition. Under shock the nerve centres cease to normally govern the organs of the body, and that includes the cardio-vascular system.

Yet to live an organism must have uninterrupted blood circulation. The blood must traverse its complete course within 23 seconds, making more than 3,000 rounds in 24 hours.

If circulation is impaired, it gives rise to various ill effects. The blood pressure drops substantially, and the tissues and cells suffer from a shortage of oxygen and nutritive substances. Life ebbs gradually.

Such is the condition that marks traumatic shock, shock from a blow or wound. Under the circumstances, the added hardships of an operation are ruled out. They involve too much of a risk. The patient may die on the operating table.

Yet the operation may be essential, and urgent.

It was found that a blood transfusion brought about a miraculous change. The tables turned. It was like a motion picture run backwards: the blood returned to its channels, its pressure rose, and it left the depths of the abdominal organs and joined the general stream in ever greater quantities. Heart activity approached normal. The patient revived. It was possible to commence the operation.

In a major battle there were virtually thousands of such cases of blood loss from wounds, and of attendant shock. And there had to be large supplies of blood on hand to cope with the demand for it.

During the war all the numerous transfusion institutes, all their branches, all the stations in all the cities and towns of the Soviet Union collected the life-saving dark red liquid. Soviet doctors, scientists and researchers worked tirelessly to supply the Soviet Army with this most valuable healing substance. Life was sent to the wounded at the front in glass jars.

But the blood in the jars would have coagulated if it had not been for the sodium citrate and other substances—all the so-called stabilizers that prevented it from clotting.

They made it possible to conserve blood for periods ranging from two to four weeks.

Unfortunately, all stabilizers possess a common fault.

Although compatibility is carefully observed, transfusions of stabilized blood are often attended by complications—vomiting, heart palpitation, headache, or high temperature. True, they are much milder than in cases of blood incompatibility, but nonetheless undesirable even in this mild form. They are caused by the stabilizers and the salt solutions in which the latter are dissolved. The organism, particularly an exhausted and badly bled organism, reacts to both.

Hence, it would be best to use blood that needs no stabilizers. And, surprisingly enough, blood taken from corpses is just that kind of blood. That is its great advantage over the blood of living donors.

Certainly, blood from corpses has to be thoroughly investigated before use. Even in the case of living donors it is not enough to take their word for it that they are healthy; their blood has also to be tested. But in the past, after the blood taken from corpses was screened for infectious diseases, stabilizers were added to it, as in the case of ordinary blood, for conservation purposes.

However, the keen eye of Dr. Skundina, an associate of the Sklifosovsky Institute, detected a dumbfounding phenomenon.

She had just poured blood freshly taken from corpses into test tubes and was about to take it to the laboratory for screening, when she was urgently called away. The test tubes remained in the rack. She was absent for two hours. The blood should have coagulated in that space of time.

But when Skundina returned she saw that it was still fluid and free from clots. This did not fail to draw the attention of the observant scientist.

Researchers began to study this amazing fact. They discovered that blood taken from corpses did not need stabilizers. It would keep for three weeks without forming clots, and if clots did appear in the first few hours after death, they soon broke up and returned to a fluid state.

Transfusion of blood from corpses, therefore, rules out complications provoked by stabilizers. The 2,500 transfusions of blood from corpses performed before 1940, and many thousands of such transfusions in later years, were all highly successful. They lowered the incidence of transfusion complications six-fold as compared to transfusions of blood from living donors.

Why does blood from corpses have this particular property? That in an interesting question. No comprehensive answer to it, however, has yet been obtained.

The most satisfactory explanation was given by Bryukhonenko and Yankovsky, two Soviet scientists.

Coagulation is caused by thrombin, a fibrin ferment of the blood. Meanwhile, a dead man's liver, spleen, bone marrow, and particularly the lungs, eject another ferment into the blood, which, according to Bryukhonenko and Yankovsky, may be called anti-thrombin.

This ferment ties up the thrombin, and coagulation, which cannot take place without free thrombin, is arrested. That explains why blood from corpses keeps well without stabilizers.

It is an excellent property, to be sure, but the blood of living donors cannot be dispensed with. The reserves of blood from corpses are limited. Moreover, not all the blood taken from corpses is suitable for medical purposes. The blood of persons who died after prolonged agony, of infectious diseases, and of injuries involving damage to the major blood vessels, is unfit for transfusion.

The living donor remains the chief source of blood for transfusions.

Hence the need for stabilizers, particularly sodium citrate, which make it possible to ship blood supplies on a large scale.

LIVING LABORATORY

ARSENTY SNEGIRYOV, plant foreman, was indisposed. He felt weak and had a splitting headache. His appetite was gone and all he wanted was to lie down. By nightfall his temperature rose slightly, showing 99° F.

Several days later he was down with typhoid. His temperature jumped to more than 100.4° F, and at times he lost consciousness.

He was ill a full month. The disease took a grave course. There were complications in the lungs and liver, and the joints. The doctors did all they could for him, but there was no improvement. The disease was getting the better of him in spite of his strong constitution.

It was at this crucial point that Dr. Batashov had an idea closely related to the problem of immunity. It was a strikingly original idea.

Immunity is the state or power of resisting a disease. Some people do not fall prey to contagion. They do not contract infectious diseases, and when they do, they overcome them with astounding ease. The symptoms of the disease are barely perceptible in them. That shows them to be immune to the disease. Such a condition may be called natural immunity.

A person who has had an infectious disease, say, typhus, does not contract it a second time. And if he should, it would be in its weakest form. The person is immune, or only slightly susceptible, to the disease. His, however, is not natural, but acquired immunity.

A vaccine is a fluid prepared from weakened or killed microbes. A vaccination is nothing but an injection of a disease in its mildest form. A person who is vaccinated contracts the disease, as it were, and thereby acquires immunity. It is artificially acquired immunity. Should a person vaccinated against, say, dysentery, later have an attack of this disease, it would be short-lived and mild.

The blood, as we know, contains red and white corpuscles. The latter, known as leucocytes, are cells that possess a highly developed mobility. They can penetrate the walls of blood and lymphatic vessels and move about in all directions. But their manoeuvres are not aimless. They converge upon foreign bodies—a splinter or a microbe—that have strayed into the organism. They attack them and if it is a germ, it often succumbs to the attack and is digested and destroyed. The leucocytes that destroy germs are called phagocytes, which means "eaters of cells."

Immunity is derived from the white blood corpuscles, which destroy germs and thereby prevent their multiplication. But when the leucocytes, for some reason, fail to cope with the microbes, there is no immunity. The microbes multiply and the disease develops.

That is how Mechnikov's phagocytic theory explains immunity. It was of tremendous importance to the progress of medicine. But it was unable to explain certain phenomena.

If we take a drop of fresh serum from the blood of a rabbit and infect it with anthrax bacilli, we shall soon see the latter diminish in number, and perish. Yet the serum has no white corpuscles. The rabbit's immunity to anthrax, it would thus appear, does not depend on the leucocytes, but on the serum, or on one of its constituents. This fact gave rise to the humoral (fluid) theory of immunity. But the humoral theory, like its phagocytic forerunner, fails to explain some pertinent phenomena.

One Soviet laboratory, for instance, made the following experiment. Typhoid vaccine, i. e., a liquid containing greatly weakened or lifeless typhoid microbes, was injected into a rabbit. Some hours later the scientist measured the quantity of agglutinins, or protective substances, in its blood serum. The agglutinins had doubled in quantity.

Then the vaccine was injected into the rabbit again, not subcutaneously this time, but under the web-like membrane of the cerebrum. As a result there were fifteen times as many agglutinins in the serum as after the first vaccination.

The action of the vaccine directly on the brain cells presumably intensified their function. The resultant stream of nerve impulses stimulated the tissues producing protective substances—antibodies—agglutinins and antitoxins. Thereby the animal acquired an immunity that was much more marked than after the ordinary vaccination.

This implied that immunization depended on the nervous system.

A toxin, or poison, produced by microbes causing tetanus—an acute and usually fatal disease—was injected into a dog's paw. Tetanus developed and brought about the dog's death. In the case of another dog, however, the poisonous injection was accompanied by a simultaneous injection of novocain.

Time went by and the dog remained sound.

Novocain deprives nerve fibres of their sensitivity to excitations. It excludes the nerve tissues from all vital activities. In the dog's case it arrested the spreading of the deadly tetanus.

This implies that the nervous system had a hand in the body's reaction to tetanus poison.

It may be safely presumed, therefore, that immunization depends on the nervous system.

An implication of this kind chimes in with Pavlov's theory about the leading role of the nervous system.

But that does not dismiss the significance of phagocytosis and the protective substances, or antibodies, of the blood and tissues. The phagocytes and antibodies are not independent entities. Their function is governed by the nervous system. And it is they that execute the all-important protective functions regulated by the cerebrum. The serum contains several kinds of antibodies—antitoxins, agglutinins, opsonins, etc. The blood of an individual who has had an infectious disease and acquired immunity, usually contains more of these substances than the blood of a person who has not had the disease.

But back to the ailing foreman. Dr. Batashov's idea was very simple. He suggested a transfusion of blood from an immunized donor, a donor who had had typhoid.

A quantity of killed typhoid microbes was introduced into the donor's system. He soon felt indisposed and feverish. It was a mild form of typhoid, and he easily coped with it. In a day or two the donor was well again. A great quantity of antibodies was produced by his blood, and he was immune to typhoid.

It was blood from this donor that Dr. Batashov transfused to Snegiryov. The patient's condition improved visibly. The disease had lost its edge. Three days later a second transfusion turned the tables in the patient's favour. He was well on his way to recovery. His temperature was dropping from day to day. Within three weeks he was able to sit up in bed. In another week he was ready to be discharged from hospital. Dr. Batashov had saved him from a protracted illness, from complications and possible death.

This case is not an exception.

On December 21, 1949, a conference opened at the Leningrad Blood Transfusion Institute under the auspices of the Ministry of Health of the R.S.F.S.R. Its agenda prominently featured the problem of immuno-transfusions. From the first the conference took an extremely interesting turn. Reports were made by bacteriologists, specialists in infectious diseases, children's diseases, and blood transfusions. They had all come from different cities and regions of the Soviet Union.

The reports favoured the idea of treating infectious diseases with transfusions of blood from immunized donors. It was clear that the idea would soon outgrow its laboratory stage and become a new weapon against a great many infectious diseases.

The reports spoke of wide-scale observations involving hundreds of child patients. They showed that a disease, if it persists, is in most cases considerably mitigated by transfusions of immunized blood; the complications, at any rate, are fewer, and convalescence much shorter.

Not all questions have as yet been solved, however, and there still are many failures in cases of typhoid, whooping cough, dysentery, scarlet fever, to say nothing of typhus and serious malaria and paratyphoid cases. It is, therefore, too early to draw any far-reaching conclusions.

All the same, the use of a donor as a living laboratory producing healing substances to combat infection, is a unique method which holds great prospects for blood transfusion.

There is another interesting side to blood transfusion.

A child had an acute case of xerophthalmia. The doctor found himself in an extremely difficult situation. He had to tell the little patient's mother that her boy, who had already lost his right eye, would inevitably lose the left eye as well.

There is a dreadful implication in the very word xerophthalmia, which is Greek for "dry eye." The cornea shrivels up and ulcers appear, followed by other serious complications. The cells of the eye—that remarkably delicate mechanism which transmits to the brain all the variety and colour of the visible world—lose their moisture. They thicken, wither, and solidify. Such cells, naturally, become opaque and cease to transmit light rays. The consequence is blindness.

The doctor was recording the results of his examination with a tarrying hand, putting off the moment when he would have to tell the mother the distressing truth. She stood before him with an expression of mingled despair and hope.

But just as the doctor was about to break the terrible news of the boy's imminent blindness, a sudden idea crossed his mind. And what he said was not what he had initially intended to say.

"Bring him to our clinic at three today," he told her. "We'll see what we can do. But don't be late."

At three sharp the boy was hospitalized. A week later he was discharged. He walked down the street holding his mother's hand, and looked up at the shapes of passers-by, at the buses and houses about him.

His right eye was beyond repair. But the second eye was out of danger. It no longer looked lifeless. Its tissues had regained normal lustre, and complete recovery was a certainty.

The doctor's sudden idea, which saved the boy from total blindness, hinged upon a blood transfusion, a rather unusual blood transfusion.

There is a class of substances whose presence in man's diet is absolutely essential. They are called vitamins. One of them is vitamin A. It occurs in animal fats, and is particularly plentiful in cod liver oil. Vitamin A promotes growth and protects the system against infection. But what is most important to us at this point, vitamin A cures xerophthalmia.

The boy's case was far gone. His eye could only be saved if the process of withering were arrested immediately. What he needed was a large dose of vitamin A. But at that time vitamin A was not as yet being produced in a form that could be injected into the blood, or subcutaneously. Cod liver oil could hardly have served the purpose. Its dose would have to be gigantic, much greater than anything the boy could hold at one time.

The doctor's sudden idea boiled down to a method of supplying the child's organism with the required amount of vitamin A. It was to be done that same day, and, what was more, it was to be done in a way that ensured its immediate assimilation.

Two hours before the transfusion the donor was made to drink a whole glass of cod liver oil. That was a dose only a healthy adult could drink at one time.

At the moment of the transfusion the donor's blood was saturated with vitamin A, absorbed from the intestines. A test made beforehand at the laboratory confirmed this. Along with the transfused blood the boy's body thus received a dose of vitamin A which proved big enough to terminate the xerophthalmic process. It saved the child's eye.

It must be borne in mind, however, that a method of this kind is applied in exceptional cases only. Not all healing substances appear in the blood of the donor in the desired form after being administered to him. But as a last resort the attempt is worthwhile.

Who knows, perhaps this use of a donor as a living laboratory for therapeutic substances, which he then gives up to the recipient, has a great future.

BLOOD'S PATH

BLOOD MAY BE TRANSFUSED into a vein, or artery. Similarly, blood may be taken from either the donor's vein, or artery.

But which is preferable?

Before answering this question let us recall the path blood follows in a human body.

The principal force propelling blood is the heart. This is a hollow organ about as large as its owner's fist. It is divided into two parts—left and right—by a partition. These two parts are sometimes called the left heart and the right heart. Each consists of two interconnected sections—the upper being known as the auricle, and the lower as the ventricle.

Hence, the heart has a right and a left auricle, as well as a right and a left ventricle.

Day and night the heart unceasingly contracts and expands. Each time it contracts it forces out blood from its ventricles. From the left ventricle the blood goes directly to the aorta, the largest of the arteries, and from there to all the other arteries. These convey it—bright red, fresh and rich in oxygen—to all parts of the body.

Used up blood, dark in colour and saturated with carbon dioxide and other cell waste, returns to the heart by the veins. The two large venae cavae feed it to the right ventricle. This completes the greater, or systemic, circulation cycle.

Now the used up blood must absorb a new supply of oxygen. That is done with the help of the lungs. The right ventricle contracts and sends the blood to the lungs, where it is oxygenated. Then it flows back to the left auricle, and from there to the left ventricle. This completes the lesser, or pulmonary, circulation cycle.

The blood flows from the auricles to the ventricles when the latter relax, or expand. Otherwise they would be empty during the next contraction and the heart would have nothing to send forth to the aorta and arteries.

The arteries and veins are connected by capillaries. Capillaries are minute blood vessels. Their walls comprise a single layer of cells. That is the thinnest kind of wall. The channel of the capillary is uncommonly narrow. It is much like the cramped little sidestreets of ancient towns, where two carts cannot pass each other. Two red corpuscles cannot travel along a capillary abreast; there is not room enough. Yet the red corpuscles are so tiny that the head of a pin could accommodate a vast number of them.

The capillaries are extremely important vessels. It is through their walls that the cells receive their supply of oxygen and nutrition brought by the blood. All the arteries break up into such capillaries.

The capillaries, which take their beginnings from the arteries, gradually widen and become small veins. These small veins pour their contents into larger veins.

In this way the arteries and veins form a single unbroken system of blood vessels.

Clearly, it does not matter much where the blood is transfused, since it completes a full round of the arteries and veins in only 23 seconds. Transfuse it to a vein, and it will reach the arteries in a matter of seconds. Transfuse it to an artery, and it will reach the veins just as quickly.

As a rule, however, blood is taken from a vein and transfused to a vein.

The veins are better suited for it. Firstly, their walls are thinner than those of arteries. Secondly, they are less resilient and easier punctured by the transfusion needle; furthermore, it is much easier for the needle to locate a vein than an artery. And whenever it is necessary to expose a vessel, to free it of surrounding tissue, it is also easier done with a vein than an artery.

Can blood be directly transfused to the heart?

Yes, it can. The needle pierces the thorax and is then gently guided to the heart cavity. After this a tube leading from the jar of blood is attached to it. The transfusion follows these painstaking preliminaries.

But it is an operation that must be handled with extreme care. Not every physician, not even every surgeon ventures upon it, and those who do, do it with apprehension.

That kind of a transfusion is made only in exceptional cases, when there has been a tremendous loss of blood, for instance, and a matter of seconds decides the issue between life and death.

ONLY A PART

IT WAS A VERY SERIOUS, third-degree scalding. The man had fallen into a cauldron of boiling water. His back and legs were a frightening sight. The pulse was almost imperceptible, and the heart was failing.

A transfusion was made the instant he was brought to the hospital. But instead of blood the doctors transfused a light, amber-coloured liquid. It was plasma.

The site of burns and scalds discharges a serous fluid. This deprives the organism of much of its liquid. The blood in the vessels thickens, and the heart has difficulty in propelling it through the vessels.

The blood must be diluted to ease the heart's burden. On this account, it is best to transfuse plasma or serum alone, without the mass of thick red and white corpuscles.

A new patient was delivered to the Clinic of Internal Diseases. The attending doctor made a transfusion, and again it was of an unusual type. Something thick and dark flowed along the tube to the woman's vein from the glass jar.

The patient had anaemia. Her blood had quite enough plasma. It was short of red corpuscles.

On occasion, it follows, doctors find it expedient to transfuse some single constituent of blood—plasma, serum, or erythrocytes—instead of whole blood.

Compatibility tests are superfluous in both plasma and serum transfusions. That is their marked advantage. Neither plasma nor serum contain erythrocytes, and only erythrocytes agglutinate in case of incompatibility. Furthermore, plasma and serum keep longer than whole blood, and may be transfused safely in very large doses.

Plasma and serum may be dehydrated and shipped in a dry state by parcel post. To prepare such dry plasma or serum for transfusion, the doctor has only to dissolve it in double distilled water.

A remarkably easy way of producing dry plasma and serum was found after a protracted search by a group of scientists of the Leningrad Blood Transfusion Institute—Depp, Filatov, Bogomolova, Shamov, and Kosumov, and several Moscow scientists—Bagdasarov, Dultsin, Rosenberg and Balakhovsky.

This greatly facilitated the use of those valuable blood products, which were particularly useful during the war.

Plasma and serum are called blood substitutes, or, more specifically, natural blood substitutes, for they are natural constituents of blood.

The blood substitute found by the Leningrad scientist Petrov has much in common with them. Petrov's transfusion fluid was widely used in the Great Patriotic War. It was, in the main, a hypertonic solution of common salt, and a few other salts, and contained a small proportion of real donor's blood. The proportion was very small, however—just ten per cent of the total volume.

Petrov's fluid was highly effective, and saved the lives of many Soviet soldiers.

There are even substitutes that do not contain any real blood. They are known by various names—the Ringer-Locke solution, Norme solution, normasol, tutophysin, transfusin, infusin, colloidal infusin, etc. All of them contain nutritive substances, which are much like the constituents of blood.

Sometimes blood is used for transfusions that has accumulated in, say, the abdominal cavity in haemorrhages from artery wounds, or the damaged veins of internal organs. However, this blood must be thoroughly filtered by means of sterilized gauze, so that it should be free of even the smallest clots.

Naturally, it must also be safeguarded against microbes.

SPECIFIC PROPERTIES

THERE ARE MANY BLOOD SUBSTITUTES. But haematologists, specialists in the study of blood, seek ever new substitutes.

Medicine is employing blood transfusions of various types. Greater use naturally means greater blood requirements. But blood supplies are far from unlimited. Hence, the demand for substitutes.

But not all substitutes may be considered fully adequate. A great many of them replace the blood to only a small extent.

The best substitute, of course, is the blood serum itself. But that, again, has to be obtained from donors, which limits its supply.

Yet there is an inexhaustible source of a fully adequate blood substitute, and that is the serum of the blood of animals—cows, and sheep, for instance. Their serum may be obtained in unlimited quantities.

But it is not done for a very simple reason. Man, cow, sheep, horse—they all belong to different species. The serums of different species are incompatible, or, as science puts it, specific to each species. Sheep's and cow's serum agglutinates human red corpuscles, causing major disorders and even death.

That is why all the attempts to transfuse animal blood to humans always had fatal outcomes.

Science was confronted with two inferences that appeared to exclude each other. One was the tremendous reserve of beneficial animal serum; the other—that incompatibility due to the difference in species robbed these reserves of practical value.

It was only in our day that the solution of this difficult problem was found. Much was done in this field by Belenky, a Soviet scientist. After a number of years of unremitting research he has found a way of processing animal serum to eliminate its specific properties.

Belenky has made numerous tests to verify whether human erythrocytes agglutinated in the obtained serum. The results were hopeful. There was no agglutination.

But these were only experiments. They were made in laboratories, in test tubes containing blood and serum. It came to a stage when the serum had to be tested in a human being.

But what man would agree to undergo the risky experiment ? Belenky found such a man. It was himself. The scientist transfused almost two glassfuls of processed cow's serum into his own system. There was no negative reaction, no sign of shock. One would think it had been human serum of his own group.

It could therefore be presumed that the specific properties of animal serum were greatly reduced, possibly even completely eliminated, by Belenky's method.

Research institutes made numerous transfusions of processed animal serum.

The Sklifosovsky First-Aid Institute in Moscow made particularly many transfusions of this kind under the guidance of Professor Arapov, and the results obtained were very good. Almost in all cases the condition of the patients improved. The transfused serum stimulated the vital activity. That was verified in thousands of transfusions.

Striking facts were published late in 1953 by Professor Uglov and Zvyagin of the Leningrad Medical Institute. In five years they made more than 500 transfusions of Belenky's serum to patients suffering from various ailments. The results were satisfactory. In each case there was a marked improvement of the general condition, just as though it had been a transfusion of ordinary blood. Furthermore, the transfusions had the stimulating effect observed in ordinary transfusions.

Research of animal serum is continuing. It is to be expected that the problem will finally be solved, since the methods of research are steadily improving.

Medicine will then receive tremendous reserves of a high-quality substitute for life-saving transfusion blood.

FURTHER SUCCESSES

The healing properties of blood discovered by the prodigious power of the human mind, had, at long last, been put to the service of health. Meanwhile, continuing scientific investigations brought to light many new valuable properties of blood.

Lung tuberculosis is known to all. The germs, which are agents of this dreadful disease, infest the respiratory organs, and multiply there. In grave cases the lung tissue disintegrates, and, what is worse, those sections of the lungs which perform the respiratory function, the alveoli, disintegrate as well. As a result, tuberculosis victims experience a shortage of air, and when they walk or move they suffer from an oppressive choking sensation.

The so-called oxygen cylinder—a container filled with oxygen which is inhaled through a tube attached to the cylinder—was to date the only known means of relief for this condition.

Recently researchers suggested blood transfusion. The blood to be used is to contain an admixture of hydrogen peroxide.

Hydrogen peroxide has a considerable content of oxygen. Once it is introduced into the body, the latter is gradually liberated, and absorbed by the blood. It compensates for the failure of the respiratory part of the diseased lung. It does not rid the victim of the disease itself, but fortifies him and improves his condition, giving the damaged organ a chance to recover somewhat.

Wounds, as we have said, sometimes give rise to shock, a mortally dangerous condition. The main trouble is that in such a condition a person cannot be operated on even if an operation is vital.

Under shock the heart is depressed by a lack of blood, which barely circulates and disappears, as it were, from the major arteries and veins, and the heart itself. It concentrates in the abdominal cavity, liver and spleen.

The nervous system is to blame for that. Shock-stricken nerve centres cease to exercise a normal control over the organs of the body, including the cardio-vascular system. As a result, blood circulation is deranged.

That leads to blood shortages in the organs, and results in oxygen deficiency. The lack of oxygen brings about a marked decrease of metabolic processes—processes of nutrition in the tissues. That is why shock is so dangerous.

A transfusion of blood saturated with oxygen restores metabolism in next to no time. Again, as we see, it is a matter of blood and an admixture of hydrogen peroxide.

Sometimes the functions of blood are utilized for purposes other than transfusion.

The efforts of another Soviet scientist, Dr. Bogomolova, have led to the manufacture of a very useful preparation. Its use is best illustrated by the case of the patient with a kidney tumour.

In 1949 the patient was brought to the clinic with a marked swelling of the left side. The doctor saw at a glance that the swelling was caused by a substantial increase in the size of the kidney due to a cancerous tumour. The kidney had grown as big as a man's head.

The sooner this kidney was removed, the better.

The operation was quite successful. But a new danger arose from another quarter—haemorrhage. The surgeon and his assistant had done a thorough job of suturing the bleeding vessels, but the blood continued to flood the site of the operation. It came from the minute arteries and veins of the retroperitoneum and mesentery, and the cellular tissue covering the vena cava inferior and the aorta. Insignificant in size, previously joined with the tumour and severed during the operation, these vessels were oozing blood, creating the threat of a dangerous blood loss. The suturing of separate vessels wrought no change.

Then the surgeon brought into play a yellowish, sponge-like substance. He dressed the affected site with it for a brief period, and then closed and sutured the wound. A subsequent examination of the site of the operation showed that it was doing well. The bleeding had stopped.

It was the sponge-like yellowish substance, a sponge made of blood plasma, that had stopped it.

Dr. Bogomolova's preparation is being ever more broadly used to arrest bleeding when other methods fail or are less conveniently applied.

LOSS LIMITS

THE TRAM'S WHEEL had totally severed the man's leg from his body. The other leg had also sustained serious injuries. It took the ambulance only a few minutes to rush the traffic victim to hospital, but for wounds of that kind a few minutes is a long time. The blood from both femoral arteries was gushing out in an intractable stream.

At the hospital reception ward the arteries were instantly sutured, and a blood transfusion was made. It brought no relief. Another transfusion was made. But in vain. The man died.

Had the transfusion been too small? No, the patient had received a sufficient quantity of blood. At the same time he was given all the necessary drugs to maintain his heart activity. The doctors did all they could to save him.

The man died because there is a limit to rapid loss of blood, after which no transfusion can be of help, especially if it is not made immediately.

Death is inevitable, as a rule, if blood losses exceed three per cent of the body's total weight. The loss of three or four quarts of blood at a time, is fatal to a man weighing, say, 132 lbs., if lost blood is not instantly replaced with donor's blood.

But a transfusion must be made, however great and rapid the blood loss may have been. Patients have been known to lose up to four quarts of blood, and yet recover. The fatal limit is not the same in all people.

Neither are the body's natural capacity to restore lost blood, and the duration of this process, always the same in all individuals.

CAUSES OF SHOCK

LET US NOW GO OVER to the question of post-transfusion shock, the shock that follows a blood transfusion. As we know, transfusions of incompatible blood give rise to grave complications, poisoning the organism, as it were, deranging the circulation, and destroying the red corpuscles. As a result, the patient lapses into unconsciousness; in many cases this condition is fatal.

How to explain the existence of blood groups and blood incompatibility? The reason for their existence is biological. The proteins in the blood serum are not the same in all persons. It is this difference that underlies the various blood groups and causes incompatibility.

Post-transfusion shock, however, is quite another matter.

It is usually thought that the recipient's serum destroys the erythrocytes of incompatible transfused blood. The disintegrated red corpuscles, and other elements in the incompatible blood act as a poison on the cells, tissues and organs of the recipient.

But such an explanation is incorrect.

Quite different processes are behind the shock caused by a transfusion of incompatible blood. Research conducted by Soviet scientists has determined the real causes of post-transfusion complications.

A laboratory experiment made with a dog is highly instructive in this respect. The number of blood vessels in the spleen, which is closely connected with the entire circulatory system, is particularly great. An operation was made thoroughly to isolate the vascular network of the dog's spleen from the rest of the circulatory system. Not a single drop of blood could enter or leave the spleen.

Unspecific blood, the blood of another species of animal, was introduced into the isolated spleen. This should not have provoked any complications. Post-transfusion shock, it would appear, was out of the question. The arteries and veins of the spleen were cut off from the rest of the circulatory system. Only its own blood circulated in the dog's organism, and there was absolutely no admixture of incompatible blood.

But a shock ensued, the kind of shock that usually follows a transfusion of incompatible blood.

This may appear very puzzling, until a certain aspect is taken into account. The nerve ties of the spleen, which connect it with the rest of the body, were not cut off. It was this that was behind the post-transfusion shock.

Transfused blood acts principally upon the nerve endings in the walls of the blood vessels, and not so much on their cells, organs and tissues. Compatible blood is a normal excitant of the nerve endings and provokes normal impulses, which, transmitted to the central nervous system, stimulate the body's vital activity. This explains the beneficial effect of a transfusion of compatible blood.

Incompatible blood, meanwhile, is an abnormal excitant of the nerve endings in the arteries and veins. The impulses it generates in them are not normal, but pathological impulses. Upon reaching the central nervous system these abnormal impulses act through the brain and play havoc with the physiological processes in the body.

It is such abnormal impulses that cause post-transfusion shock. The leading role, as we see, is played by the central nervous system, and its supreme division—the cerebrum.

Pavlov's teaching on the part played in the body by the nervous system sheds light on the action of compatible and incompatible transfused blood.

ARMY OF FRIENDS

In the Soviet Union donors are treated with great concern. Their health and living conditions are thoroughly investigated. Donorship is honoured. The outstanding social service of those who give their blood to the sick, is rewarded with "Honoured Donor" badges.

In 1919 there was one donor in the entire Soviet land. It was the girl whose blood Shamov used for his first blood transfusion. Now there are tens of thousands. It is a veritable army of men and women with a highly developed sense of duty and fellow feeling, an army of friends.

Blood transfusion is organized on a great scale. Even pre-war figures speak of this.

There were 2,433 blood transfusions in 1932, 22,160 in 1935, and 100,143 in 1938, while in 1940 their total jumped to 226,000.

Wide use of conserved blood was first made in 1934, when 4,429 of the total 12,942 transfusions, or 26 per cent, were made with conserved blood. In 1938 this figure climbed to 70 per cent, and in 1940 to 90 per cent.

These figures mirror an improvement in blood conservation methods, methods of stocking up large blood reserves, and better preparedness in coping with the contingencies of the struggle for health.

In the Great Patriotic War of 1941-45 the splendidly organized blood transfusion service saved countless wounded soldiers.

There it stands, this "ampoule of life," in the refrigerators of hospitals, clinics and first-aid stations, ready at any moment to show its remarkable healing power in the fight with death. The "ampoule of life" is never empty. The donors, whose ranks are growing from day to day, see to that.

* * *

In the Soviet Union scientists and entire institutions carry on their work under exceptionally favourable conditions. Like all public health facilities, blood transfusion has always been a matter of state concern.

The Moscow Institute of Haematology and Blood Transfusion, the first of its kind in history, was founded in 1926. In its wake similar institutes were established in almost all the major Soviet cities—Kharkov, Leningrad, Tbilisi, Minsk, and others.

The guiding principle of Soviet power is the welfare of the people. The Soviet state spares no expense in developing blood transfusion and extending the network of transfusion stations.

In 1941 the U.S.S.R. had about 1,500 institutions specializing in blood transfusion. Furthermore, research and practical application of transfusion was promoted in their various districts by all the major hospitals in the country. Today every single point in the Soviet Union, including the Far North, has transfusion facilities.

Like all other forms of medical treatment, even the most complicated blood transfusions are made free of charge. Their cost is covered by the state budget.

In its study of problems bound up with blood, Soviet research has left no stone unturned. The theory explaining the stimulating action of transfused blood originated in the Soviet Union. Soviet scientists were the first to produce dry blood plasma and serum. They also made particularly great progress in blood conservation, and the search for blood substitutes. Soviet institutes made use of the blood of corpses, and thereby lowered the incidence of post-transfusion shock. It was first determined in the Soviet Union that blood collected during medical blood-letting is fit for transfusion purposes, and it is in the Soviet Union that the possibilities of adapting incompatible blood, and the heterogenous blood of animals, are being studied.

All these achievements have secured for Soviet medicine a leading place in this particular field. The reports of Soviet representatives provoked great interest at all international congresses on blood transfusion.

CHAPTER TWO
DEATH DECEIVED

JULIET

WILLIAM SHAKESPEARE'S Juliet drank a sleeping potion, and her sleep was so sound that her parents took her for dead. She had a lavish funeral, and her body was placed in the family crypt.

Shakespeare described the episode with such masterly vigour that one cannot help believing it, believing everything, that is, outside the implication that a sleeping person could be taken for dead, and buried. That could only have happened in the absence of a doctor.

The doctor would not have failed to see that she only slept. He would have heard her heart beating. Very faintly, perhaps, but beating nonetheless. He would have found her pulse, weak as it was.

Whatever sleeping potion Juliet had taken, her heart could not have stopped. She would never have awakened if it had.

UNTIL THE HEART STOPS

SOMETIMES A SICK person cannot sleep. At other times he sleeps unusually long.

But there is a disease in which the patient sleeps all the time. Sleep, as a matter of fact, is its only visible symptom.

This disease is known as the sleeping sickness. It is marked by a peculiar condition which has all the appearance of deep sleep. Shake the "sleeper," or shout in his ear; he will not wake up.

His state of lethargy may last a day or two, a week, two weeks, even months.

The patient is alive. His heart functions, though weakly. He breathes, though only superficially—the movements of his chest are barely visible. Sometimes breathing may stop, but only for a minute or two. The patient is alive as long as his heart beats, although his appearance is quite that of a corpse.

Attempts are made to wake the "sleeper," if only for a short time, in order to feed him. And if these attempts fail, the doctor resorts to artificial feeding. If the patient is not fed, he will die of starvation.

When the heart stops for a bit, or respiration ceases, that does not always signify death.

In my last year at medical college I attended an operation on a painter of about thirty-five who had stones in his right kidney. The kidney had to be opened and the stones removed.

The operation was well on its way when the surgeon, a Professor Volkovich then prominent in Kiev, exclaimed:

"The blood's getting dark! Watch his heart!"

No sooner had he said that than the painter's heart stopped. The pulse vanished. Respiration ceased.

Anaesthesia was instantly terminated, and the operation put off. Camphor and caffeine were injected to stimulate the patient's heart. Simultaneously, the surgeon applied artificial respiration. But the heart would not respond.

The painter's face was pale. The nails of his fingers became ominously blue.

The surgeon picked up a long needle. He looked at it pensively, as if weighing his chances. It was only for several seconds, but they seemed an age to me. At last he made up his mind. He pierced the chest with the needle, thrust it carefully into the patient's heart, and injected a solution of adrenalin. A heart beat followed. Then another. And finally the heart began to beat stronger and faster.

Adrenalin is a potent heart stimulant which is often of help when all other means have failed.

The injections—camphor, caffeine and adrenalin—took about three minutes. All this time artificial respiration was being applied without stop.

We heard a faint sigh. Reviving heart activity was marked by reviving respiration.

Several minutes later the operation was resumed and brought to a successful end.

The patient, who was still under the effects of the anaesthetic, was no longer pale and his finger-nails had regained their normal colouring.

I remember all this clearly, because it was the first time I saw a man's heart stop, and then beat again. He had been lifeless for two or three minutes. Two or three minutes more, and death could not have been averted.

Every surgeon has encountered cases of this kind in his practice.

The patient returned to life because all his organs were still viable. His heart was not worn out when it stopped. It could have functioned indefinitely under normal circumstances. Its failure was caused by chloroform. An overdose of chloroform is a poison to the respiratory centres, to centres regulating cardio-vascular activity, and to the heart itself.

An operation may last an hour, or more. Within this time the chloroform is usually unable to cause irreversible changes in the organs. If timely notice is taken of everything that may befall the heart or respiration, things can still be put right.

Surgeon Volkovich had an intimation of disaster when he saw the colour of the patient's blood. Blood grows dark when it lacks oxygen. And it lacks oxygen when it stops circulating and no longer reaches the lungs to get fresh supplies. The surgeon had to act swiftly. There was no time to lose.

The surgeon applied artificial respiration and made injections of heart stimulants—camphor and caffeine.

But the camphor and caffeine injected subcutaneously could only reach the heart, or the brain centre governing respiration, with the blood. The patient's blood circulation had ceased, however, and, to all intents and purposes, the injections were useless. One thing remained: to inject a stimulant directly into the heart. And it had to be a potent one. Volkovich used adrenalin.

Surgeons sometimes open up the thorax, expose the heart, and massage it with their hand. That, of course, is an extreme measure, but it is worth while as a last resort.

AFTER IT STOPS

A BIT OF TISSUE TAKEN FROM a fully-developed embryo of a chick was immersed in a special solution known as nutrient medium. The tissue continued to live. Its cells broke up. New cells replaced the dying ones.

The chick could have grown up to become a hen. The hen could have reached old age, and died. But the bit of tissue taken from it when it was still an embryo, lived on and on.

Only the medium had to be changed from time to time.

Thus, bits of tissue can live longer than an entire organism.

A geologist friend of mine died of pneumonia at the hospital where I, still a young doctor, worked at the time.

Streptocid, sulfidin and penicillin were unknown at the time, and pneumonia was a very dangerous ailment.

This was in Petrograd. The mother of the deceased was summoned from Moscow by telegram.

The geologist died at mid-day. His mother was to arrive the following morning. The geologist, who had been ill a week, was unshaven. I did not want his mother to see him that way, and had him shaved. But next morning, when I entered the morgue, there was hair again on his cheeks. It had grown overnight.

If a section of tissue with hair follicles is placed in a suitable nutritive medium, the hair will grow for quite some time.

Professor Kravkov, a gifted Soviet scientist, devoted himself to pharmacology. He studied the effects of drugs on human beings, and made many extraordinary and valuable investigations, particularly of isolated organs.

Kravkov passed a fluid nutrient known as the Ringer-Locke solution through the blood vessels of a finger cut off from a corpse.

He analyzed the fluid after this procedure. The result was surprising. The fluid that left the finger was different from the fluid that he had introduced into it. New substances appeared in it.

These new substances were produced by the tissue cells of the finger; they were products of their vital activity.

To a certain extent the solution had replaced the blood. It supplied the finger's tissue cells with the necessary nutritive substances, which the cells assimilated and then excreted as products of metabolism.

In other words, the tissues of the corpse's finger acted much like living tissue.

AT PHYSIOLOGICAL LABORATORIES

KULYABKO, THE TOMSK PHYSIOLOGIST, did with a thyroid gland what Kravkov had done with the finger. That is, he introduced some Ringer-Locke fluid into the excised gland's artery. The fluid circulated through the gland and emerged from the opening of a vein. Kulyabko collected it as it flowed out, and discovered that it contained the hormone of the thyroid gland.

The gland was by no means dead. It was alive and continued to secrete its hormone. Clearly, some organs of a corpse long retain their vital properties, provided they are placed in a suitable medium.

This is also true of more complex organs.

Professor Kulyabko performed another astounding experiment. He placed a dark, roundish, somewhat elongated meaty object into a unique apparatus with glass and rubber tubes, and a small electric motor. The meaty object was an ordinary human heart.

The professor had taken the heart from a corpse 24 hours after death. The little motor pumped Locke's solution, a variety of nutrient medium, into the heart by the glass and rubber tubes. And the heart of a day-old corpse began to beat.

Bryukhonenko and Chechulin, two Moscow physiologists, made another remarkable experiment. They beheaded a dog, and made its head live on for a while. It opened its eyes, closed them in strong light, and then opened them again. When acid was applied to its lips, its tongue licked it off. The head even pricked up its ears at the sound of a whistle.

Bryukhonenko and Chechulin sustained the head's life by passing a nutrient medium through its arteries.

The experiment took time and patience, extensive knowledge and much imagination, painstaking preparations, practice, and cleverly-designed apparatus.

A series of failures finally culminated in success.

The Moscow physiologists proved that even the cerebrum was able to function for some time after all signs of life in it should have terminated.

Subsequently the two researchers drew upon the daring experiments of Andreyev to revive dead animals.

DISTANT VOYAGE

BUYAN LIVED with all the other laboratory dogs.

He was a strong, cheerful and good-natured animal, barked merrily and wagged his tail whenever he saw the professor. The professor would pat Buyan in passing on his way to his study. The scientist and Buyan were great friends.

One day Buyan was brought to the laboratory. The dog was placed on the operating table, and was soon deep in a narcotic sleep. The professor and his assistants began an operation.

They were getting Buyan ready for a distant voyage.

They pierced his major neck artery and let out all his blood. His heart stopped beating.

The professor pulled up Buyan's eyelid. The eye was lustreless and glassy. The dog was dead.

All this time special devices were recording the dog's respiration and heart activity. A black line marked each sigh on the white sheet of a turning drum; another line, parallel to the first, registered the heart beats. In the early stages of the operation the lines rose and fell regularly, mirroring normal respiration and heart activity. Then the ebb and flow became sporadic and less pronounced, and finally disappeared altogether; the two lines were as straight as an arrow.

This showed that respiration and heart activity had ceased, and that the dog was dead.

But the blood drained from Buyan's body had been preserved. It flowed down a tube into a large glass vessel, part of a specially-designed apparatus known as the autojector, which was connected to a little electric motor.

A needle, which was connected to the glass vessel by another tube, was pushed into the dog's neck vein. Five minutes went by, and then another minute and a half. The dog's body, lifeless and motionless, lay on the table.

The professor's eyes were fixed on his stop-watch.

The crucial moment arrived. Not a second was to be lost.

The professor turned the tap and switched on the motor. Oxygen flowed with a hiss into the blood in the glass vessel. The motor pumped the blood and the oxygen into the vein. The blood was just like that which had passed through the lungs during respiration.

The motor worked uninterruptedly, pumping blood into the dog's blood vessels. The blood reached the animal's heart, and was distributed from there to the tissues and organs. After making its full course through the body, it poured out again from the tapped artery in Buyan's neck. It streamed back into the glass vessel, where oxygen was added to it, and its cycle began all over again. The lines of the recording apparatus, however, remained as straight as an arrow. The dog's heart was inactive; respiration was absent.

Then the pulse line trembled slightly, and in a few seconds it gave a faint little leap. Then it made another leap, this time a bigger one. The respiration line rose and fell almost imperceptibly.

This marked the first heart beats, and the first heaves of the thorax. A minute later the dog sighed and a faint shiver ran down its body. The dog was coming to life. Soon Buyan breathed normally, and the heart beat as usual.

In several minutes the apparatus was removed, and the needles, with their rubber tubes, were pulled out of the artery and vein. There was no need for them any longer.

A few days later Buyan barked merrily again whenever the professor came into sight.

Buyan had no inkling of his distant voyage.

In the olden days people would have called it a voyage to the valley of death.

SIX MINUTES

BRYUKHONENKO AND CHECHULIN turned the living dog into a corpse for a mere six minutes. On the seventh minute they lost no time in reviving him.

In another two or three minutes nothing could have brought Buyan back to life.

Irreversible changes would have occurred in some of his cells, extinguishing all hope of revival.

Let me explain. Death means a stoppage of all functions, including nutrition. When nutrition ends it puts a stop to metabolism and deranges all intracellular processes. The cells, deprived of their nourishment, decompose and disintegrate.

At that stage no amount of nutrition can revive them. To put it in another way, the mechanism which disassimilates, or breaks up proteins and other organic compounds, and assimilates, or digests their nutritive particles, is hopelessly wrecked. The damage done to it is irreversible.

Nutrition ceases at the moment of death. But irreversible changes occur some time later.

The cells of some organs are hardier, less complex, and more stable. Irreversible changes take a longer time to come to these hardier cells. The cells of other organs are delicate and vulnerable. They begin to disintegrate sooner, giving rise to earlier irreversible changes.

Some cells live quite some time after their owner's death; the epithelia of the skin, for instance, and the cells of the hair and nails.

The nerve cells of the brain, particularly of the cerebral cortex, are the most delicate and unstable. Irreversible changes occur in them very soon after death.

Kulyabko's experiment with the heart showed that the cells of the heart muscle remain viable as long as 24 hours after death. Brain cells perish much sooner. With them it is not a matter of days or hours, but of minutes. They remain viable for barely five or six minutes after respiration and blood circulation cease.

Yet it is the brain cells that govern the body's principal vital functions.

That explains why Professors Bryukhonenko and Chechulin so keenly watched the hand of their stop-watch. They made sure that the changes in Buyan's brain cells did not last longer than six minutes. Otherwise nothing could have brought the dog back from his distant voyage.

NOT THE HEART ALONE

In neglected tuberculosis the lung tissues disintegrate. But doctors have now learned to cure the disease, provided treatment is begun early enough. If the moment is lost, the disease develops, disintegration spreads to ever new areas, and the patient is in mortal danger.

There is a disease known as pyonephrosis. This disease destroys the kidneys. Morbid changes affect the calyces and tubules, which are the kidney's most vital parts. If the disease is allowed to progress in both kidneys, it is fatal.

One more disease, cirrhosis of the liver, is much like tuberculosis and pyonephrosis. It destroys the tissues of the liver. If allowed to develop, it causes death.

Patients who die of these diseases cannot be returned to life after their hearts stop beating. The treatment accorded to Buyan would be futile in their case. Blood injections would not make them breathe again, not even if only two of the possible six minutes passed after death.

These patients need more than a functioning heart to return to life. What they need is sound lungs in one case, sound kidneys in another, and a sound liver in the third. And medicine, so far, is unable to provide a patient with new lungs, or a liver.

Those who die of protracted chronic ailments or dangerous infectious diseases, both of which cause substantial changes in the vital organs, cannot be returned to life. In such cases death is unavoidable.

Doctors try to stave off the death of such patients for as long as possible. They do not lay down their arms until the last minute, until the patient's dying breath, and fight the disease with all the means at their disposal.

But if death sets in, the doctor's mission is over.

It is quite another thing, however, if death strikes a person unexpectedly. No exhausting ailment has worn down his health, and his internal organs have not fallen prey to any chronic disease. Sometimes cases like that arise during operations, even comparatively simple operations.

In some rare cases it may be the anaesthetic that paralyzes the heart or the respiration. Death follows. But if heart activity and respiration are revived without delay, the patient will live.

In other cases a person may suffer injuries in a traffic accident, and loses much blood. His heart stops, but if the doctors succeed in reviving its function, the traffic victim will be restored to life.

In war traumatic shock is often more dangerous than the wound. Under its effects the nervous system fails to function properly, and the heart, and respiration, are on the verge of stopping.

If shock is not treated soon enough the heart and respiration will come to a standstill, bringing on death.

But if the heart is made to function again and simultaneous measures are taken to end the shock, complete recovery is practically certain, since all the patient's organs are intact.

Negovsky, the Soviet scientist, has long worked on this problem. After years of experiments with animals he was finally able to work out a new method of reviving prematurely terminated life.

During the Great Patriotic War Professor Negovsky fought tooth and nail for the life of wounded Soviet soldiers, making death retreat whenever there was still a spark of life left in them.

DEATH IN RETREAT

ARTILLERY SERGEANT CHEREPANOV was brought to the field hospital with a shattered right thigh. The wound was extremely serious. The arteries, veins, and nerves in the thigh zone were torn to shreds. The bone had suffered also.

The Soviet Army Medical Service functions like clockwork. The sergeant was removed from the field at the height of battle in a matter of minutes. Two hours later he was brought to the field hospital.

All possible aid was rendered to him immediately. Hot water bottles were put all round him, his injured blood vessels were sutured, and blood transfusion was made. But Cherepanov was suffering from severe, third-degree shock. He lay on the operating table pale as a sheet, his eyes lustreless, his pulse and respiration almost extinct. Camphor was injected, then caffeine and adrenalin, and, finally, a physiological saline solution. But it was all to no purpose. The sergeant's faintly beating heart stopped. He died.

The attending surgeon wrote in Cherepanov's registration card: "Died from shock and acute haemorrhage on April 8, 1944, at 19 hours 41 minutes."

These were to have been the final lines of the Russian soldier's life story.

But just then people in white gowns entered the operating room. They were Professor Negovsky and his assistants, Smirenskaya, Litvinova, and Kozlov.

Negovsky was on a tour of front-line medical establishments to try his method of fighting death under front-line conditions. That was how he came to the field hospital where Cherepanov had just died.

Every second counted, and the professor lost no time in starting in upon the patient. Two minutes had passed since the sergeant's apparent death. In another minute the professor's assistants were at their stations, and Negovsky was bending over the man, who was, to all intents, a corpse. The professor's curt orders broke the silence of the operating room.

Do you remember when the sergeant died? It was at 19 hours 41 minutes.

At 19 hours, 45 minutes, 30 seconds the first new entry was made, containing just three words: "First heart beat."

A second entry was made at 19.48: "Neck muscles contract. Natural respiration has begun." More entries followed: 19.56—"Respiratory movement of thorax"; 20.00—"Sigh. First movement of diaphragm"; 20.07—"Pupil reflex"; 20.45—"Regaining consciousness"; 23.00—"Condition serious. Sleeps. Wakens easily. Replies to questions. Complains of blindness. Quickened pulse—114 per minute, weak. Respiration deep, regular."

Twenty-four hours hence the entry was: "Sight fully recovered. May be moved to rear."

There is hardly any need to add anything to these entries. Professor Negovsky had made death retreat from Sergeant Cherepanov's bedside.

SECRET OF SUCCESS

Had Professor Negovsky invented some special apparatus or some miraculous life-restoring device? Or had he used some new drug?

Nothing of the kind.

True, Negovsky had some equipment with him, but it was no larger than a common handcase. It was a short rubber tube and miniature, specially-designed bellows.

That was all, outside of the professor's hands and knowledge.

Negovsky's triumph over death was the result of knowledge accumulated during long years of experimental research.

He resorted to artificial respiration. But he applied it in an unusual way. One of his assistants inserted the rubber tube directly into the sergeant's windpipe and pumped air into his lungs by means of the bellows. The lung tissue expanded and assisted the influx of air. The ensuing impulses in the minute branches of the nerve endings in the lung walls travelled to the respiratory brain centre and prompted it to resume its activity.

Artificial respiration was accompanied by a blood transfusion. But the transfusion was also unique.

The blood was transfused into an arm artery, instead of the usual vein. It was not simply transfused, but pumped under considerable pressure with the aid of the so-called Bobrov apparatus. This had a decisive bearing on the entire case.

Professor Negovsky had to make the sergeant's heart resume its function.

The heart cannot function if it is not supplied with blood by its vessels. The sergeant had lost too much blood. Although a transfusion had been made previously, Negovsky thought it wise to repeat it, but in his own way.

The heart revives quicker if its muscle is rapidly supplied with nutrition. Nutritive substances, therefore, must be brought directly to the heart muscle as quickly as possible.

The blood, pumped into the arm artery, and flowing from there to the aorta in a direction opposite to its natural course, caused the aortal heart valves to shut.

The shut valves prevented the blood from reaching the heart cavity, and it was obliged to travel directly to the coronary arteries, which branch off from the aorta in the close proximity of the heart. This was achieved by pressure feeding with the aid of Bobrov's apparatus.

The coronary vessels are two small arteries girdling the heart and supplying the heart muscle with blood.

The transfusion of 300 cc of blood into the artery, of all the other possible places, and under pressure, of all the other possible ways, was meant to bolster the heart in the shortest possible time, to nourish the heart muscle and call forth the first contractions, the first heart beats, which would facilitate the speediest delivery of blood to the brain centres.

The first blood transfusion was immediately followed by another.

This time 700 cc of blood were transfused in the usual manner through the vein, in order to make up for lost blood.

Thus, the first 300 cc were designed to feed the heart itself, and the later 700 cc—to fill the blood vessels.

Negovsky also employed adrenalin—that powerful stimulant of heart and vascular activity. But, again, he did it in his own way. He added the adrenalin solution to the 300 cc of blood transfused to the coronary arteries.

The acute shortage of oxygen, and the accumulation of harmful products of metabolism in the blood and tissues—both caused by the failure of blood circulation—were the main danger. Sergeant Cherepanov's heart had been totally immobile for four minutes, and the oxygen deficiency in his system was so acute that it menaced the cells and tissues with a biological catastrophe. The sooner the oxygen would be delivered, the sooner this menace would be eliminated.

Negovsky added some hydrogen peroxide to the 700 cc of blood transfused to the vein. Hydrogen peroxide quickly gives up its oxygen to the blood. He also injected a 40 per cent solution of glucose, a highly nutritive substance.

That was all he had time to do in eleven minutes.

As you see, Cherepanov's resurrection was not a miracle. Knowledge gathered in the course of long years of experimental research was translated into action.

THE LAST WORD

SERGEANT CHEREPANOV'S death lasted 4 minutes 30 seconds.

Meanwhile, six minutes is the limit of viability for the brain cells. If Negovsky's operation had begun 2 or 3 minutes later than it did, Sergeant Cherepanov could not have been saved. Negovsky's method is effective only if it forestalls irreversible changes in the cerebral cells. A person is not really dead, we might say, until irreversible changes occur in his body, though his heart may have failed and he has stopped breathing.

Such death is known among doctors as "clinical death." It has all the outward symptoms of death—absence of respiration, heart action, pulse, and pupil reflex. But it is not as yet biological death, for the cells still retain their viability. It is only the threshold of death, only its initial stage.

Real death is biological death, which involves the disintegration of cells. The first to come to ruin are the most valuable and vitally necessary cells, such as the cells of the central nervous system.

To cut a long story short, Professor Negovsky's method is indispensable during death agony, and may also be effective in certain cases of clinical death.

On his tour of the front-line hospitals Professor Negovsky performed fifty-four operations.

Fifty-four mortally wounded men of the Soviet Army were in the grip of death. Conventional medicine was helpless. Forty-four of them were in death agony, and ten had already died.

Professor Negovsky intervened and drove off death in all the forty-four cases of agony. All the forty-four men were returned to life. Whatever eventually happened to them depended on the nature of their wounds. A day or two later, twelve of them were fit enough to be evacuated to the rear.

For the other ten clinical death had set in two or three minutes before Negovsky's arrival. In five of these cases his efforts were in vain, for biological death had succeeded clinical death.

The length of time preceding irreversible changes in the cells and tissues presumably varies in different persons. For five of the men, it transpired, it was less than six minutes.

The other five were returned to life. Four of them soon parted with it; this time for good. But it was not Negovsky's method that had failed in their case. They would have lived if their wounds had not been so grave. The most perfect heart and respiration could not have saved them, considering the terrible damage inflicted by bullets and shell fragments to their internal organs.

The fifth and last of these ten was Sergeant Cherepanov.

Negovsky's method, as we see, offers the doctor most valuable aid in his fight against the fatal consequences of traumatic and operative shock, death from anaesthetics, mortal losses of blood, and electric shock. It is also an indispensable factor in cases of agony.

In effect, it is the only means to drive off real death once clinical death has set in.

And as Negovsky's method progresses with time, it will unquestionably make death beat a retreat ever more often, giving place to life wherever irreversible changes have not affected the cells.

In the years that followed Sergeant Cherepanov's remarkable return to life many more lives were saved by Negovsky's method in many cities of the Soviet Union.

OUTSTRIPPING THE CENTURIES

THE ADVANCED METHODS of Soviet science, and especially Negovsky's method, could have returned to life thousands of victims of early death. The solution of this humane problem could have yielded remarkable results if it had not been for the grim time factor that stands in the way of sweeping success. The six minutes within which the changes in the cells of the central nervous system, and principally those of the cerebral cortex, are still reversible, are a very short time.

In spite of wonder-working methods, medical aid is too easily liable to be late. No wonder researchers glued their attention to the time factor. Each extra minute would mean an extra chance of saving a great many people, and an extra ten or fifteen minutes would practically solve the issue.

The question arises, why the cells of the central nervous system, and particularly those of the cerebral cortex, are so fragile that the changes in them become irreversible in the short time of six minutes.

Soviet physiologists have revealed most interesting particulars about the respiratory processes. Respiration, they discovered, does not abruptly cease at the moment of dying, and passes several consecutive stages.

At first respiration becomes irregular. The breathing comes in gasps, then it becomes convulsive, and this is followed by isolated sighs and lengthy pauses. Finally, the thorax becomes motionless.

Soviet scientists found the explanation for these respiratory phases. The active cells of living organs generate currents known as bio-electric. The cells of the cerebral cortex also generate such currents. These can be detected and recorded with sensitive electric appliances. But when death sets in and respiration is paralyzed, the appliances record nothing—the currents vanish. The absence of currents indicates that life has left the cortex and certain other sections of the central nervous system. Regular breathing ceases at that moment. But respiration does not. It continues, but its regular rhythm gives way to convulsive and sporadic gasps.

The cortical cells regulating respiration have ceased to function. Since respiration continues, however, there must be other cells that govern it.

The pupil reflex, or the pupil's reaction to light, which is still intact at this stage, indicates that the section of the brain beneath the cerebral cortex continues to function. The cells of the still active breathing centres are located in that section.

Only the disappearance of the pupil reflex would indicate that the brain cells in this zone have ceased to live. But even at this stage respiration would not stop. It would continue in isolated gasps followed by drawn-out pauses. This kind of irregular breathing marks the death struggle.

Certain other cells of the respiratory brain centre obviously survive at this stage. It was determined that they are seated in the medulla oblongata, or the spinal bulb.

Only a totally motionless thorax will serve to show that the medulla oblongata has become defunct, and death is imminently close.

Researchers have also discovered other facts. The duration of the reversible changes varies for the different brain cells. The cells of the breathing centre in the medulla oblongata may be revived after thirty minutes of death, for instance, while the time limit shrinks to ten, and even six minutes in the case of cells located nearer to the cortex.

Why do the cells connected with the respiratory function, and particularly those closely linked with the cortex, undergo irreversible changes so much quicker than the other cells of the organism?

A curious biological fact came to light. Only the higher species of mammals possess a developed respiratory centre in the cerebral cortex. This signifies that the respiratory centre appeared at a late stage of the evolutionary development of living nature and belongs to animal species that evolved comparatively recently, perhaps only one or two million years ago. It is the youngest development of the central nervous system.

It is this that lies behind its unusual sensitivity to harmful phenomena, its frailty and vulnerability. Perhaps in men of the distant future these centres of the cerebral cortex will become less vulnerable, and in a few million years the duration of their reversibility will presumably increase.

Are we then to wait millions of years before the duration of reversibility will increase by several minutes?

Clearly, progressive science cannot reconcile itself to such a long wait. As Michurin put it, "We cannot wait for favours from Nature; we must wrest them from her." In studying the objective laws of nature, Soviet science intervenes actively in biological processes, refashioning them to suit man's needs. Professor Negovsky, whose views we have outlined, and others working on the same problem, confront the task of achieving today what nature would normally grant only in millions of years.

Death from drowning is caused by absence of air, i.e., of oxygen. But a drowned dog is returned to life with greater ease if it drowns in an anaesthetized condition. It may even be revived after a longer period of submersion than a dog who had no anaesthetic.

When mountaineers reach high altitudes they experience dizziness and weakness, and often lose consciousness. This is explained by the rarefied air, or, again, by a shortage of oxygen. But if the victims of this "mountain sickness" are given a soporific, Luminal for instance, this condition is easier overcome.

Professor Galkin, a Leningrad patho-physiologist, discovered an amazing phenomenon: many properties of the organism undergo great changes under the effects of narcotic sleep. Anaesthetized cells can live under conditions that would be fatal to them under ordinary circumstances.

Galkin's discovery explains why victims of the "mountain sickness" are relieved by a dose of Luminal. The soporific modifies the reaction of the tissue cells to oxygen deficiency. They get along on a smaller supply of it. A dog pulled out of the water in an anaesthetized condition could be revived because it was able to get along on the negligible quantity of oxygen contained in its organism.

This property of anaesthetics may possibly point to a way of delaying irreversible phenomena in cells. Death from the failure of respiration, after all, is essentially death from oxygen deficiency.

It may be presumed, if only hypothetically for the time being, that even a small dose of an anaesthetic administered during the final minutes of agony, will preserve a flicker of life in the cells after all other means fail. Life would be sustained by that negligible quantity of oxygen always present in the tissues and the blood, a quantity much too small under normal conditions.

This state—where the heart and the breathing would have stopped—would still be clinical and not biological death. Perhaps it would last for more than 5 or 6 minutes.

The duration of reversibility would grow longer for the cells of the higher sections of the central nervous system, and this gain in time would promise a greater degree of success in reviving the life of the clinically dead.

Soviet scientists will doubtlessly find effective means to triumph over premature death.

ON PAVLOVIAN GROUND

It is now quite clear that the central nervous system and, more specifically, the cerebral cortex, plays the leading role in all the processes of death and re-animation.

But what is the nature of these processes from the viewpoint of Pavlov's teaching ?

That is not merely a question of theory. If the proper answer is found to it, it will no doubt open new horizons to the fighters against premature death.

Two facts have been established beyond question.

Firstly, the cells of the cerebral cortex cease to function and perish earlier than the other section of the brain. The cortex is the most sensitive and fragile part of the cerebrum, while the medulla oblongata is the most enduring, and dies later than the others.

Secondly, a reverse action is observed, as it were, when an organism is being revived. The centres in the medulla oblongata revive before the other brain centres. The cortex cells are the last to revive, coming to life after all the other sections of the cerebrum.

Only Pavlov's teaching can explain these phenomena.

What, indeed, is the failure of the cerebral cortex in the initial stages of death but a phenomenon of defence ? The unusually sensitive cells of the cortex cannot long endure hardships and adversities. When the situation deteriorates and blood circulation stops they try to save themselves from complete exhaustion and ruin by ceasing their function. This reaction is achieved through inhibition.

Inhibition sets in at the very outset, safeguarding the vulnerable cortex cells from exhaustion in their struggle for life.

During the death struggle the heart continues to function, though weakly, and respiration, though irregular, continues as well, while consciousness is totally absent. That means the function of the brain cortex was stopped by inhibition. Otherwise an irreversible exhaustion of its cells would be inevitable. Such are the benefits of protective inhibition.

Certain facts noted by Professor Negovsky are inexplicable unless viewed in the light of Pavlov's ideas.

In a number of experiments serious injuries were inflicted to dogs. If the subjects were in a protracted state of excitement before the injury, barely 2 or 3 minutes of clinical death were fatal to their brain cortex. Death became inevitable.

Light was also shed on observations of persons saved from drowning. Those who drowned without a long struggle after quickly losing consciousness, and went to the bottom like a stone, so to speak, were comparatively easy to revive. Things were much worse with those who struggled and exerted all their strength to remain on the surface, labouring all the while under a powerful psychic strain.

The less victims expended of their muscular and nervous energy, the less they exhausted the cells of their cerebral cortex.

Such is the part played by inhibition in the dying phase.

As for the phase of re-animation, let us recall that respiration and heart activity are the first to return. But both the heart beats and respiratory movements are irregular and come in fits and starts. That means the medulla oblongata is back in operation, while the cortical centres are still inactive. They remain under the sway of inhibition. And rightly so. If the cerebral cortex were to begin its function early in the process of revival, when the organism is as yet unable to provide its cells with normal nourishment and metabolic condition, the powers of its frail cells would be over-taxed. They would again be confronted by the menace of exhaustion and death. Continuing protective inhibition safeguards them from this fatal denouement. It is only after the physiological function of all the other organs is more or less back to normal that the cortex cells can safely resume their function. Inhibition is lifted, and the organism's revival is complete.

This is the picture we get of protective inhibition, both when life ebbs, and when it revives. It opens new horizons to medicine in the latter's fight against premature death.

Indeed, since inhibition of the cerebral cortex cells is beneficial, could it not be artificially produced whenever desired?

The researchers at Negovky's laboratory tried it on some victims of traffic accidents. When brought to the clinic these badly mutilated people were, as a rule, in their death agony. An immediate blood transfusion was made to them. But it was combined with a new procedure: a small dose of Pentothal Sodium was transfused together with the blood. The Pentothal Sodium, an anaesthetic, was designed to promote protective inhibition. In many of the cases this purpose justified itself. Cases of death agony gave way to returning life. Inhibition of the cerebral cortex cells, reinforced by Pentothal Sodium, played an important part in their revival.

Artificial inhibition also safeguards the cerebral cortex from premature revival, which is attended by the danger of exhaustion for its frail cells.

But even under protective inhibition the vulnerable cortex cells cannot survive the adversities of a defunct blood circulation and deteriorated nutrition for more than five or six minutes. After this the changes in the cells become irreversible, and inhibition gives way to final extinction. The longer this irreversible phase continues, the less hope there is for a full or partial revival of life. The cells of the medulla oblongata and the sub-cortical centres must also not be allowed to remain inactive for too long. If their revival is delayed, the changes in them become irreversible as well.

This is not mere rhetoric. The experiments of Professor Asratyan have fully confirmed it.

The professor deprived the brain of a dog of its normal nourishment. He did it by compressing all the arteries leading to the brain. In the case of one dog the brain was drained of blood for a period of 20 minutes, after which the blood vessels were unclamped and normal blood circulation was restored.

The dog survived. But it was unable to stand or walk, and lay on its side all the time. It could not even stretch itself. All its complex reflex actions vanished. It was much like the dogs whose cerebral cortex and midbrain had been removed.

In the case of another dog the brain was drained of blood for 16 minutes. It could stand and walk and stretch itself after the operation. But it would not learn to approach a platter of food, for instance, or respond to a name. It had lost all of its conditioned reflexes, and was much like the dogs whose cerebral cortex had been surgically removed.

The brain of a third dog was drained of blood for six minutes. It remained its usual self after the operation, and behaved just like any other normal dog.

These experiments demonstrated the importance of the duration of clinical death caused by a stoppage of blood circulation through heart failure, or by other reasons leading to irreversible destructive changes in the cells of the cerebral cortex.

When studying the problem of premature death and re-animation all these implications must be borne well in mind.

That is how Pavlov's teaching explains the processes attending death and re-animation. The following words of the great physiologist are quite apt: "What a vast and fruitful field would open for physiological research if immediately after an induced disease, or by virtue of inevitable death, the experimenter would, well in command of all the knowledge in this field, seek a means to conquer the one and the other."

Certain recent scientific facts hold out a promise of interesting developments. The application in surgery of hypothermia, or the cooling of a patient's body to the abnormally low temperature of 83°-86°F, may tend to lengthen the term of reversibility to 25-30 minutes. This is treated in greater detail in the chapter on heart surgery.

* * *

The problem of lengthening life requires considerable study. The discoveries of Soviet scientists fill us with confidence that the goal will be reached.

"Death is a fact that must be studied... To study means to conquer." (Maxim Gorky)

CHAPTER THREE

FIGHT FOR TIME

TO LIVE A THOUSAND YEARS

IN 1778 A STARTLING rumour spread in the medical world. It travelled from lip to lip and aroused heated discussion.

Man's life span could be extended to a thousand years, the rumour said. And though most doctors sceptically shook their heads, there were those among them who were inclined to believe the possibility of such a discovery. It was linked with the name of John Hunter, the scientist who was said to be conducting mysterious experiments in the privacy of his cellar. Two years later Hunter published a treatise on human longevity, and gave a detailed account of his investigations. Man, he said, grows markedly older after fifty. If it were possible to arrest the vital functions of his body at that time of life, the wear and tear on the tissues would be eliminated. Man would then live longer. Many times longer, anyhow, than if his body were functioning normally.

The treatise suggested cold as a means of arresting the vital functions of the human organism. Cold puts a stop to all vital processes. Frozen meat, for instance, neither spoils, nor decays, no matter how long it remains on ice. Thawed after six months, a year, or even more, it is perfectly fresh. Fruit also keeps long on ice without spoiling.

Hunter conceived the idea that the same would hold true for man. He proposed that persons reaching the age of fifty be put on ice. They would not die... nor live. All the functions of their body would come to a standstill. But no part of them would deteriorate or decompose. Forty years hence, when they would be ninety, they should be thawed back to life. They would again eat, drink, sleep, walk, and work like all other ordinary people. They would live an active life for ten years, and learn about everything that had taken place in the preceding forty. They would live through the entire span from their fifty-first year to their hundredth within that one decade.

When the ten years would be over they were to be frozen again; this time for ninety years. But on the ninety-first, or, rather, their hundred and ninety-first year, they would be thawed back to life. Books and newspapers would tell them of the events that took place while they were out of circulation. They would again live an active ten years, and return to their icy sleep at the turn of the eleventh. They would be two hundred, and would remain on ice for another ninety years. In their two hundred and ninetieth year the procedure would be repeated.

In this manner, Hunter asserted, life could be made to extend over a thousand years.

But the author made no actual attempt to lengthen his own, or anyone else's life. His reasoning, he claimed, was perfectly sound, but nothing could as yet come of it in practice. His experiments with carps had failed.

The five carps that he had put on ice, froze stiff. After ten days they were put into a warm bath. But they remained just as motionless in the water, as they had been on ice. They were dead.

After his fantastic experiment had failed with fish, Hunter would not risk it with a human being.

STRANGE PHENOMENON

THE SCIENTIST'S DISAPPOINTMENT was mingled with surprise. The death of his carps puzzled him. He anatomized them, making a thorough study of their internal organs.

Did he find that the blood had expanded and burst the blood vessels, that the heart had been unable to endure the cold, or that the swimming bladder had burst, perhaps, or the liver injured in some way?

No, Hunter found everything intact. All the carps' internal organs were in perfect order. There were no signs of change. That added to his surprise.

One day the corpse of a peasant was found in the open field. The cold had been unusually great, and he had frozen to death. It was determined that he had lain in the snow for 14 days. He was a tall man, and had a very strong constitution.

The autopsy was performed by an experienced dissector. The absence of an eye was all he could record. But it transpired that the deceased had been one-eyed from childhood. The internal organs were all intact. The dissector could not say whether death was caused by heart paralysis, stoppage of respiration, thrombosis of the arteries, failure of the liver or kidneys, or by some other cause. He discovered no clue whatsoever. There were no morbid changes in the body.

The dissector had known beforehand what to expect of the corpse of a man frozen to death, but this was the first time he himself was making an autopsy of this kind, and the freshness of the tissues and organs astonished him. Freezing is not attended by any outward morbid phenomena. The same is true of separate limbs, or parts of a human body—arm, leg, wrist, foot or finger—affected by frost-bite. Even a microscope reveals no changes in the structure of tissues or cells of the affected limbs. The skin of a frozen part turns white and becomes insensitive to pinpricks and pressure. But that is all.

The changes set in only after the victim is taken out of the cold and thawed. There appear oedema, black spots, decay, and, finally, necrosis, or mortification of the tissues.

In 1812 many Frenchmen froze to death along the road of their retreat from Russia. Larrey, the senior surgeon of Napoleon's army, was struck by the fact that only slight injuries seemed to ensue when soldiers did not warm their frost-bitten arms and legs by the camp-fires, while the arms and legs of those who did, presented a horrible sight; what with their black spots, their terrible swelling, and the decay. Larrey concluded that the camp-fires were responsible. The heat they gave off was too great. The sharp transition from extreme cold to extreme heat, he reasoned, caused the frozen limbs to decay.

Throughout the 19th and the early 20th centuries it was thought that thawing was responsible for the serious degeneration of frost-bitten organs.

THEORY OF EFFECTS

SOME FORTY YEARS AGO a medical journal printed an account of what a certain surgeon did to a man with a frost-bitten left arm. He thawed the victim and did everything else that doctors were wont to do in that day when treating frost-bite. But a few minutes before thawing the surgeon performed an interesting experiment. He compressed the subclavian artery of the patient's healthy right arm. In other words, he prevented the blood from entering the sound arm. As was to be expected, the arm turned blue, a state known in medicine as cyanotic.

Then the surgeon compressed the subclavian artery of the frost-bitten left arm. A highly curious detail came to light. The skin above the frozen portion of the arm turned blue, just as it should under compression. However, the frozen portion of the arm, extending from the finger tips to the wrist, did not change colour. It remained just as white as it had been before the artery was compressed. There was not the slightest hint of blue.

What did that mean? Why did the healthy arm appear lifeless when its artery was compressed, while the frozen portion of the left arm remained the same ivory white?

A scientist named Lake tried to explain this strange phenomenon. The blood vessels of a frost-bitten organ contract, and their lumen becomes narrower. In such contracted vessels blood circulates in much smaller quantities than usual. That is why the skin turns white. There is blood in the affected vessels, but its supply is very small.

This condition produces a series of effects. The cold deranges the blood circulation in the tissues. Metabolic processes in the frozen cells weaken. The cells cut down on their consumption of nutritive substances and expel only a small quantity of waste products. And since metabolism is sustained by oxygen, their oxygen requirement drops sharply. They get along on a very small quantity of blood.

When the surgeon compressed the artery of the frozen arm the negligible amount of oxygen that seeped through the constricted vessel sufficed to feed the cells with their sluggish metabolism. The frozen hand and wrist which got along on this negligible supply, did not turn blue.

It was different with the right arm. Its healthy cells required a normal supply of oxygen. And when the compressed artery cut off the usual inflow of blood, cyanosis was the natural result. That was how Lake explained the surgeon's experiment.

But why do frost-bitten limbs eventually turn black, and decay?

Lake's explanation was very simple. As the frost-bitten limb thaws, he averred, the blood surges back to the site of the frost-bite in a liberal stream, so that the vessels, contracted and paralyzed by cold, are unable to cope with it, and allow it to pass through their walls. This causes the oedema. The oedema presses on the cells. The cells, functioning below par, lack their usual power of resistance, and succumb to the oedema.

The quicker the thawing, the greater the blood stream rushing to the frost-bitten cells. The greater the blood stream, the worse the cells cope with it, and, hence, the speedier their disintegration. On the other hand, the slower the thawing, the greater the chance for the cells to survive.

Although Lake lived almost a hundred years after Larrey, their views on the matter were identical.

WHAT THIS MEANT

IN 1936 I WAS SPENDING the winter in Taganrog. The house I lived in adjoined the hospital. The winter that year was unusually cold. As I was leaving my house one day, a sledge drove up to the hospital gates, trailed by a dog. In the sledge a fowling-piece and game-bag lay desolately by the side of a black-bearded man whose legs were wrapped in a blanket. A second man, who sat next to him, was holding up his head and shoulders.

The gates were flung open, and the sledge drove into the hospital yard. Curiosity got the better of me, and I followed the strange procession—black beard, dog, gun, game-bag, and all. The sledge stopped by the porch of the casualty ward. The black beard's companion vanished behind its door, and soon returned in the company of two white-gowned men.

"Legs gone to the dogs," the black beard said. "Get me to a fire—Quick. It's cold as the devil."

But one of the white-gowned men replied:

"That'll have to wait. We must first rub some life into your legs. Right here, out in the cold."

They raised the blanket and pulled off the patient's top-boots and foot-cloths. I was struck by the ivory-like, yellowish hue of his bare shins and feet. The white-gowned men took handfuls of snow and rubbed his naked legs, talking to each other and questioning the black beard about his mishap.

I was all eyes and ears. I gathered bit by bit that the black beard had gone hunting and strayed into a swamp. The thin ice gave way under his weight and the hunter got his feet wet. A peasant came across him and brought him to the hospital. The white-gowned men rubbing the hunter's legs with snow, were a doctor and his assistant.

"Don't rub too hard," the doctor said to his helper. "The toes may break off. See—they're as hard as icicles."

The hunter kept groaning all the time, and begged them to take him indoors to the fire.

"Not a hope," the doctor replied. "Or you'll have to part with your legs altogether. They've got to recover out in the cold. Grin and bear it."

Two hours passed. The doctor finally stopped rubbing.

"They're warm now," he said.

The hunter was then carried into the warm ward.

Was the doctor right to have kept the patient out in the cold? Yes, according to the prevailing notions of his day he was.

From time to time prominent specialists affirmed in the columns of the medical press that quick thawing of frost-bite was ill-advised. One scientist went so far as to suggest burying the frost-bite victims naked in the snow, since snow was only a bit warmer than the surrounding air; after a while they were to be put into a cold bath, and then to bed in a cold room only slightly warmer than the water. At this stage, the scientist proposed, the doctor should start massaging the victim.

This extreme bordered on the insane, but it showed how deeply people were convinced in the need of a very gradual transition from cold to warm when treating frost-bite. It was this that lay behind the traditional frost-bite treatment. Patients were not brought into heated premises. The rubbing and the massage were performed out in the cold—the yard, or an unheated room.

This was the method of gradual thawing. It was a method accepted by most doctors and was also widely known to laymen.

That was why the black-bearded hunter was massaged out in the yard and was long denied the warmth of the ward.

What is more, the doctor was afraid to break his frost-bitten toes. Like many other doctors, he was convinced that frost made frozen tissue as hard and brittle as glass.

AFTER FROST-BITE

SOME TIME AFTER the thawing the skin of the frost-bitten part swells up, turns black, and blisters. The muscles under the skin turn black as well. Often the bones are also involved in the morbid process. The entire part grows numb. This may last for weeks and months.

The picture is not always the same in all cases. Sometimes the ivory-white appearance and the oedema vanish after the skin is massaged and thawed. The burning pain ceases, and the fingers and toes return to normal.

This comparatively happy ending is observed in frost-bites of the first degree, the least serious type of frost-bite.

But if blisters and large oedema appear, and the surface of the skin turns black and necrotic, that forbodes lengthy confinement. Even after convalescence the frost-bitten organ will often suffer aches and pains. It will often swell up, and turn red in the cold. That is second-degree frost-bite.

Third-degree frost-bite has the gravest consequences. The surface layer of skin perishes. The hypodermic tissue, the tendons, muscles, and bones, perish as well. They turn black, as though charred, and suffer necrosis, i. e. mortification. This lasts for months. Finally the dead tissue falls off, and there remains just the stump of the foot or hand. Third-degree frost-bite turns people into cripples.

Frost-bite used to be treated by surgeons. The frost-bitten tissue turned black and was dead. It was amputated along the line where it bordered on sound tissue. Better still, a bit of good tissue was cut off with it for good measure. The incision was then sutured to ensure a proper stump. An artificial limb is easier attached to a well-healed stump. This treatment, it would appear, was quick and radical, and appeared to be the most expedient.

But ever more facts indicated that the amputation did little good. At the time of the early amputation the course of the ailment is as yet obscure, and tissue is excised that could well be spared. Every fraction of an inch of muscle, skin, and tendon, meanwhile, is of the greatest value to its owner, and lessens the degree of his incapacitation.

Moreover, surgeons complained that the operation wound took unexpectedly long to heal. The stump festered and showed signs of necrosis. After a time it would often be necessary to prune off another piece of gangrenous stump, and frequently a third operation followed the second.

The cure, it turned out, was neither radical, nor quick.

Surgeons began to avoid such operations. The view gained strength that frost-bitten tissue should not be treated surgically, and that it should be spared. It was recommended to apply warmth, diathermy, and rest-cures; everything, in a word, except the knife.

The active surgical method gave way to a passive conservative method, a method of temporizing. Frost-bitten tissue was allowed to necrose, to turn gradually into dry, black, mummy-like matter, which finally fell off. Cells of sound tissue gave off growths. A scar appeared. If it was a sound, unfestering scar, it was permitted to remain. If not, it was pruned, and the wound was sutured to form a new, better scar.

The conservative method gained predominance.

But was it a good method? Well, it was. Anyhow, it was better than the surgical method. It crippled fewer people. But it also had its disadvantages. The decaying tissues poisoned the body, causing harm to such vitally important organs as the liver, kidneys, the heart, and the blood vessels. In some cases the infection spread from the affected tissues, which were infested with microbes, to the rest of the body, and caused sepsis, or general blood poisoning. The conservative method was not all one would wish it to be.

But at the time medicine knew no better way of combating the consequences of frost-bite. From time to time a scientist would try to improve upon the existing frost-bite treatment. Hundreds of researchers tackled the problem in France, Britain, Japan, Germany, and

Italy. Particularly during the First World War, when numerous soldiers fell prey to frost in the front-lines and in the rear. But all efforts failed.

A new and radical solution was found only recently by Soviet scientists.

QUIET SIDESTREET

IN THE NOISY NEIGHBOURHOOD of the Finnish Railway Station in Leningrad there is a quiet little sidestreet with tidy sidewalks and well-tended trees. It bears the name of Botkin, the eminent Russian doctor. Old-fashioned squat two-storeyed houses line one side of it. A massive four-storeyed building stands on the other. All these buildings belong to the Kirov Military Medical Academy.

The extreme section of the four-storeyed building houses the department of hospital surgery headed by Professor Girgolav, Member of the Academy of Medical Science of the U.S.S.R. The department has its own clinics, laboratories, and faculties.

Professor Girgolav's day may begin in more ways than one. The morning I visited him, he was studying a report. It was a comprehensive description of two hundred cases of dangerous traumatic shock. The report outlined the causes, the results of treatment, and the final outcomes. Months of painstaking work were squeezed into six closely-written pages. They were part of a fat sheaf of scientific material awaiting the approval of the eminent scientist. The documents represented anall-embracing study of the vast experience accumulated by Soviet medicine in the Great Patriotic War. The conclusions it would lead to were to serve the medical profession in its every day practice. The highly important task of elaborating upon war-time medical experience was set by the Soviet Government.

The stocky, grey-haired man, his general's shoulder-straps protruding from under the folds of the snow-white gown, listened attentively to his assistant's report. Then he took up the sheets of paper and examined them. A visit to the wards and an examination of patients were scheduled to follow the report.

At the clinic and its laboratories his numerous pupils were at work on problems of great scientific and practical significance. But of all the things they did, their work on frost-bites was the most fruitful and interesting.

LATENT PERIOD

THE TEMPERATURE OF a frost-bitten foot is from fifty to seventy degrees Fahrenheit, which is about the temperature of a fairly warm Leningrad summer day. But for the human body this temperature is disastrous. Its normal temperature is 97°—98° F. If tissue is long kept at 50°—70° F, it will turn black and die as soon as it is thawed. That is exactly what happens in frost-bite.

But what if the same tissue is cut away and cooled to 28° F, a temperature below freezing-point?

A film of ice will cover it. And surprisingly enough, if it is kept at that temperature for, say, three days, and then unfrozen, it will neither turn black, nor die. In a nutrient medium its cells will multiply and live. Implanted upon someone's skin, it will take root and act as any normal tissue.

After thawing, as we see, the slice of tissue retains all its vitality. As part of the body, however, it perishes at a temperature much higher than 28° F.

A rabbit kept for several hours at 60° F, would die. Its internal organs would perish at such a temperature. But in an experiment the rabbit's salivary gland, a fairly complex organ, was removed and cooled to 33° F for a period of 32 days. It was then thawed and implanted to another rabbit. The gland took root and began to function normally, while in the rabbit's body it would have perished at a much higher temperature.

To the researcher this phenomenon was of paramount importance. Tissue which was part of the body, and tissue isolated from the body, reacted to cold differently. A condition that was fatal to the first, was harmlessly endured by the second. The tissue in the body, it turned out, was much more sensitive to cold than tissue removed from it.

This was highly surprising. It should rather have been the reverse. There is a system of blood vessels, nerves, and glands of internal secretion, whose task it is, among other things, to maintain an even temperature throughout the body and rush aid, as it were, to places where the thermal balance is upset. It would appear under the circumstances that the endurance of tissue to cold should have been greater. Yet hundreds of experiments proved the contrary.

Tissue that is part of the organism is dependent upon general biological processes and subject to definite laws governing the organism. One such law says that cold delays all chemical processes. The complex processes in a living organism are biochemical. Hence, in a frozen organ all the biochemical processes are reined in.

But while frost-bite affects the arm, leg, ear or nose, the rest of the body retains a normal temperature of 97°—98° F. And, naturally, where the temperature is normal, the biochemical processes also proceed normally. In this way frost-bite creates two different regions, one with a retarded, and the other with a normal vital activity.

This dual situation, this double life within a single, integral organism, cannot last long. The frozen region with its low temperature and sluggish processes must finally perish. All this takes place in the cells before the morbid deformations of the tissue become visible to the eye. There is every reason to believe that the damage to the tissues is invisible for a certain period, known as the latent period.

That is why doctors never detect any morbid changes in the corpses of men frozen to death. Not even with the aid of the microscope.

It is during this latent period that the sluggish biochemical processes take place, which are incompatible with the vital functions of the other parts of the body.

The secret of this incompatibility still remains unsolved. But it has been determined beyond doubt in numerous experiments that the time factor is extremely important. If the slow-up of vital processes is avoided, everything may turn out well. The sooner these processes return to normal, i.e., the shorter the latent period, the less the extent of damage. If the latent period is very short, there will only be changes that are known as first-degree frost-bite. A longer latent period gives rise to second-degree damage. And an extensive period of latent changes is fraught with injuries that are known as third-degree frost-bite.

A still longer exposure to cold will cause the gravest possible consequences of the third degree, consequences so serious that they could well form a category of their own—that of fourth-degree frost-bite.

Lengthy exposure to cold extends the area of sluggish processes until they involve the entire body. The heart stops and respiration ceases. The victim freezes to death.

This, in very general terms, was what Professor Girgolav and his associates, Aryev, Sheinis, and others, concluded from their many years of research.

NEW PRINCIPLES

A NEW METHOD OF TREATING frost-bite took shape. Its principle was to reduce the latent period of sluggish processes. The affected tissue had to be returned to its normal temperature as quickly as possible. The thawing had to be immediate, instead of gradual. The victim of frost-bite had to be brought to a warm room without delay, placed in a warm bath, and massaged.

The experiments made some seventy years ago by Lapchinsky, a Russian scientist, bear out Professor Girgolav's findings. Lapchinsky froze dogs, and then unfroze them. He did this to sixty dogs. He cooled their bodies to a temperature where their respiration ceased and the heart stopped beating. All sixty were frozen in the same manner, with a mixture of snow and salt.

The thawing, however, was effected in different ways. Twenty dogs were placed in an unheated room. They gradually regained their body temperature, and returned to normal. This was a very slow method of thawing. Only six dogs survived it. Fourteen died.

Twenty other dogs were placed in a cold bath. At first the water was at freezing-point. Then it was made warm, and gradually hot water was added to it, until it became almost hot. The dogs were then removed from the bath and taken to a well-heated room. This was also a slow method of thawing, but it was much quicker than the first. Twelve dogs returned to life. Eight perished.

The final twenty dogs were placed in a bath heated to 98° F. All twenty returned to life. Lapchinsky's experiments were highly convincing. Many years hence, Girgolav's clinic yielded no less convincing results.

Lake's theory on the need of allowing the blood vessels to expand gradually, was refuted. The method of gradual thawing turned out to be incorrect. Soviet researchers upset a concept that was dominant for more than a century. A new principle replaced the old. It advocated immediate thawing in a warm room.

The nerve elements of the frost-bitten site should not be ignored. Quick thawing returns them to their normal state much more rapidly. Warmth, which is a thermal stimulant to the receptor nerves, generates processes in all the organs and tissues of the body through impulses to the central nervous system, and thereby speeds up the return to normal of the cold-stricken area. That, in effect, is the principal benefit of quick thawing.

An energetic massage out in the cold is only an alternative which should be applied if no warm dwelling is available in the vicinity. It would be unwise to wait idly until the victim, overcome by the cold somewhere out in the forest, far from human habitation, can be brought to a warm dwelling.

ANOTHER ERROR

AT THE LABORATORY they exposed a white mouse to the action of a 4° F frost, augmented by ethyl chloride, which lowered the temperature another 11° F.

The white mouse was kept in this temperature for five days. It froze to the marrow. Its tail was then bent to the shape of the letter 'o'. It bent readily, but did not break.

This proved that frozen tissue, and even entire organs, do not become brittle from cold. The hypothesis of their glass-like fragility is a myth.

Yet the opinion that frost-bitten parts of the body became brittle under the effects of cold, and had to be handled with care, had held sway for centuries. This misconception, nurtured by men little acquainted with medicine, was also taken for gospel even by prominent specialists.

Thus, one foreign 19th-century surgeon wrote in his handbook: "A completely frozen leg may be shattered like glass." Another prominent surgeon insisted that "the tip of a frozen ear or nose may be broken off." A third warned in his instructions on massaging frost-bitten limbs that "care must be taken not to break the frozen extremity."

The myth had unfortunate consequences. Mindful of the fancied fragility of frozen organs, doctors used to massage the frost-bitten limbs with such undue care that gradual thawing was even more delayed, and this caused additional harm to the patient.

We speak here of ordinary frost-bite, of the actual temperatures at which people freeze. A peculiar fragility of the tissues may be possible, we daresay, at a temperature of not less than 130° F below zero. But cases of that kind have never been recorded. Should anyone ever freeze to that very low temperature nothing on earth—no rubbing or massage—would be of any avail.

According to Girgolav the massage must be both vigorous, and gentle. Injuries to the skin weakened by frost should be avoided, as this would lay it open to invasion by germs.

Thus, Soviet science blasted one more misconception. It was an important gain in the fight against frost-bite.

AN EXIT

QUICK THAWING and vigorous massaging cannot totally prevent necrosis of the tissues. Not even when applied in a room or bath at 86°—95° F.

Lengthy exposure to cold cannot pass entirely without consequences. But by reducing the time of the action of the cold, i. e., the latent period of sluggish biochemical processes, quick thawing brings the consequences down to a minimum. Experiments on animals, and human experience show that the area of necrosis is much smaller after quick thawing than after gradual thawing. Quick thawing, as it were, turns second-degree frost-bites into frost-bites of the first degree, and third-degree frost-bites into frost-bites of the second degree, etc. As a result, doctors succeed in saving a greater part of the affected tissues.

This comparison of the old and new methods of first aid shows that the new treatment is more effective. But first aid, though highly important, is only one side of the question. It is followed by a period of treatment designed to eliminate, or minimize the damage done by the frost to the tissues.

Under the old surgical method the affected part of the limb was amputated. It was presumed that decomposition extended no farther than the area of the frost-bite, the area that turned black and necrotic.

That was an error. It was revealed that blood vessels, nerve fibres, bones, and muscles far beyond the frozen area also succumbed to the prolonged effect of cold, although the damage long remained invisible.

The surgeon making his incision above the line of frost-bite thought he was cutting sound tissue, which would later form a good stump. But as it turned out, he was handling pathologically changed tissue and a good stump was scarcely to be expected. What was more, the operation itself only made the damage worse. The operation wound festered. That is why the old surgical method was defective.

The method of temporizing was also a failure. Products of decay were absorbed by the body from the affected part, and poisoned the vitally important organs, causing them great harm. While the affected area passed from one stage to the next—from moist to dry necrosis, to what is known as mummification, and then to the stages of separation, granulation and, finally, to stump formation—all this time harmful products of decay penetrated to other parts of the body.

The surgical method could have been more effective if the operation would be made at a time when this would not endanger the neighbouring sound tissues, and if a single operation would do. The temporizing method could have gained from a reduction in the duration of the various stages of decay, since that would reduce the harmful effect of the products of decay.

Just this occupied the people of Girgolav's clinic. The comparatively simple method they evolved to solve a problem that had for centuries appeared insolvable, scarcely mirrors the tremendous effort made by the researchers in finding it.

Necrotomy, for instance, yielded excellent results in the serious (third and fourth degree) cases of frost-bite. Necrotomy is simple dissection of necrotic tissue. The knife cuts the skin, the hypodermic tissue and the muscles. It produces a longitudinal slit. Only mortified tissue is cut. Sound tissue remains untouched. The incision is made at least half an inch away from the sound tissue. The operation is painless, for the nerve fibres in the necrotic area are dead.

If the necrotic area is large and involves, say, three-quarters of the foot, part of the dead tissue is amputated along with the dead phalangeal bones. But this is done only in the gravest cases, when frost-bite affects an extensive area. More often than not simple necrotomy is quite sufficient. It provides an exit to the serous fluid produced in the bottom layers of the frost-bitten tissue. As a result, the body absorbs less of the poisonous products of decay. The operation exposes all the layers of the necrosed zone—the "weeping," decaying tissue—and, consequently, speeds its drying. The transition from moist to dry gangrene is quicker.

The stage of mummification, in which an operation becomes possible, may be brought closer by directing a ceaseless stream of dry warm air from an electric air-heater at the necrotomy wound.

By reducing the duration of the various stages, necrotomy also serves to relieve the morbid processes which develop imperceptibly in the area adjoining the affected zone. That, on the one hand, and quick mummification on the other, bring nearer the possibility of amputation and facilitate the formation of an enduring and useful stump. These facts combine to eliminate the shortcomings of both the old surgical, and the conservative, methods.

This was a mere outline of what is quite an effective treatment for frost-bite—the treatment elaborated by Professor Girgolav and his associates. Naturally, there is still a lot of work ahead. There are still certain gaps in both the theory and practice of it. In the main, however, Girgolav's clinic has solved the problem.

BAD CASES

In the early spring of 1944 I visited a northern front-line hospital. The Army Medical Service major, who was in charge of it, showed me round. As we walked down the corridor, we met a patient perambulating with the help of a crutch.

"That's what wet feet and eight hours in the snow did to him," the major said.

The patient, a lieutenant, was in command of a group of ski scouts. He was in ambush in deep snow for eight hours. He could not budge or stir all that time. There was a spring under the snow, and the lieutenant got his left foot wet. In winter moisture is worse than the frost itself. The lieutenant could not change his footwear under the circumstances, and the wet foot froze. It had seemed at first, the major informed me, that they would have to amputate the foot, and maybe part of the shin. Yet he only lost his big toe and a bit of skin on the heel.

"Saved by a warm room and a bath," the major explained. "He was lucky. The headquarters of a near-by unit were housed in a well-appointed farmstead. Besides, there was a smart sanitary instructor on the spot. He knew what to do with frost-bite."

A warm bath, a good massage, another massage with alcohol, and hot tea—that saved the lieutenant's foot. He would not have come away so lightly if he had been thawed out in the open.

"We'll discharge him in about a fortnight, fit as a fiddle," the major said. "He'll go right back to his unit."

Meanwhile, the best he could have hoped for in the past would be an amputated foot.

The wards for third- and fourth-degree frost-bite patients presented an uncommon sight. It was stifling hot in them. The patients in the beds were visible only from head to midriff. The rest of them was hidden under a kind of grotto. The grotto was made of wire arches covered with a bedsheet and blanket. There was a grotto on every bed. The major raised the cover of one, and a stream of hot air rose from it. Electric bulbs were blazing inside the grotto, attached to its wire arches. The warmth they gave off served to dry the decaying feet of the frost-bite victims.

"They're very helpful," the major said of the grottos. "All the inmates of this ward had a necrotomy. Their necrosed feed are all laid open. The necrotomy and the hot air cut down the period of convalescence."

Then he pointed at a round-faced chap of about twenty-five: "Take him, for instance. His foot was frozen right up to the ankle. He was in a bad way. In the past he'd have to spend a year or two in hospital. And he'd leave it a cripple, his foot amputated half-way up the shin. But he's spared all that anguish now."

The man had been in a field hospital a month prior to coming to the major's institution some six weeks before the day I saw him. The major said he would be discharged in two or three months.

"He'll have an amputation," the major continued. "And we'll give him a good artificial foot for the one-third of his foot that will have to go. He'll walk as fast as you or I, and he'll even dance."

We inspected two more wards. Black feet that looked as if they were charred basked in the warmth of the grottos. They bore signs of numerous necrotomic wounds. Other wards were for patients with frost-bitten hands and wrists. The grottos in these wards were designed to accommodate arms and hands.

The major suggested that we return to the ground floor.

"I'll show you similar patients on the way out," he said. "They're convalescents."

A poster on the wall of the spacious ward wished the outgoing patients farewell and good luck. There were about fifty soldiers and officers here. Several of them were on crutches.

"They're leaving us today," the major remarked. "Most will go back to their units. Others have furlough and will visit their homes. All of them are well, and not a single one of them has been here for more than six months. Some of them are unfit for military service—those on crutches. But you can count them on the fingers of your hand. In the past not less than every nine out of ten patients ended up as cripples, but it's all different now. And all thanks to the quick thawing and the necrotomy. Sollux, sun-lamp treatment and various tonics, and good food and exercise, and many other things, have a hand in it, too, but Girgolav's method is the main thing."

A GREAT BLESSING

ALMOST FOUR WINTERS of the Great Patriotic War many thousands of Soviet soldiers and officers led a tense front-line life in the forests, mountains, and tundras of the hoary north with its continuous snowstorms and frost.

The hospitals at the Karelian Front and in the immediate rear were designed to accommodate a great number of expected frost-bite cases. And this made the absence of such cases all the more conspicuous. Indeed, the number of frost-bite patients was unusually low. What was more, most of them got well in double quick time. Many of them went back to their units. They returned without the tip of a finger or toe, or with surface scars, but that did not stand in the way of their military service.

A great many did not go back to the firing lines. These had suffered more telling losses—part of two or three fingers or toes, or entire fingers, and bigger and deeper scars. They were no longer fit for military service, but were, in effect, good for almost any kind of work.

The complete invalids could be counted on the fingers of one hand. This was true not only of the Karelian Front, but of all the other fronts as well, and it was unheard of in the history of wars.

The entire country saw to it that the men of the Soviet Army would be dependably protected against the cold and equipped with everything they would need to combat frost-bite. They had good footwear, felt boots, sheepskin coats, warm foot-cloths, and sweaters.

The unprecedentedly high percentage of quick recoveries was achieved by the new frost-bite treatment elaborated by Professor Girgolav's department of the Kirov Military Medical Academy in Leningrad.

Several hundred thousand of the millions of men who heroically defended their homeland against the Hitler armies along a front of many thousands of kilometres, and who endured four war winters undaunted by the frost and the ice-cold water of the rivers and swamps, have the Girgolav clinic to thank for the wonder-working treatment that helped them to recover from frost-bite.

In peacetime people in the northern and middle latitudes of the country also expose themselves to the danger of frost-bite.

Almost powerless in serious cases of frost-bite some ten years ago, doctors today know how to lessen the suffering and reduce the harassing and unpleasant treatment which of old almost invariably involved the prospect of incapacitation.

CHAPTER FOUR

WONDERS OF SURGERY

TWO CENTURIES AGO

A PROMINENT 18TH-CENTURY biologist built a pond in his garden and put some tritons into it. He fed them, and spent days studying their habits. He noted down all his observations in a record book. But he did not confine himself to mere observations.

At first glance his experiments with the tritons may appear strange and cruel. From time to time the biologist fished a triton out of the pond and inflicted injuries upon it. Not some trifling injuries, but serious ones, like cutting off a leg, for instance.

In the end all the tritons in his pond underwent such operations. One had its leg cut off, another its tail, a third the mandible, a fourth—part of its eye. Many of the tritons had more than one operation.

This went on for three months.

It would appear that the biologist's tritons were thoroughly maimed. But far from it. At the end of three months the pond dwellers had normal limbs, mandibles and eyes. All their lost extremities had grown anew, and were of the same shape and size as the old ones.

The biologist, who took great pains with his records, registered the number of parts he had amputated in his experiments. The total was 687. And just as many had regrown.

What the biologist had observed was the unusually developed faculty of tritons to regrow lost limbs and organs. It is known as the faculty of regeneration.

REGENERATION

LIVING BEINGS POSSESS the faculty of regeneration in varying degrees. A lizard caught by the tail escapes with ease, leaving the tail in the grip of its enemy. It saves its life at the price of its tail. But it does not run around tailless for long. After a time it grows a new tail. This may occur repeatedly in a lizard's lifetime.

A complete new organism develops from any severed part of an ordinary fresh-water Hydra. Cut it up into 10 or 20 pieces, and each piece will grow to become a new Hydra with its own digestive cavity, and tentacles surrounding the oral opening.

The planarian, a flatworm occurring in ponds and swamps, is a more complex creature than the Hydra. It has a head, an intestine, a nervous system, muscles, and a pharynx. Yet if it is cut up into bits, each bit will develop into a new planarian with its typical shape of body, its own intestine, nervous system, and muscles. But that is not all. Cut a planarian's head into several longitudinal strips without severing it from its trunk, and each will soon grow into a head of its own. In this way a Soviet biologist produced many-headed creatures that, in miniature, resembled fairy-tale monstrosities.

A crawfish regrows a lost nipper. A tadpole quickly reproduces a lost leg. Birds do not regrow heads or legs, but they, too, possess the faculty of regeneration: a damaged beak, for instance, will regrow in part. This is particularly true of the duck.

Chasing the hare, the wolf or fox often catch hold of it by the skin of its back, where the hare's skin is thin and only loosely attached to the hypodermic layer. The hare escapes, leaving part of its hide between the beast's teeth. The wound on its back heals quickly and the hide is soon replaced.

The hairy integument of a squirrel's tail also reproduces uncommonly quickly.

The degree to which the faculty of regeneration is developed in the various tissues of animals depends upon the conditions of their existence.

Recent Soviet research tends to upset some of the existing notions on regeneration. It was previously assumed that the more highly developed an organism—with its greater differentiation of tissues and cells, and their complex biological functions and physiological processes—the more limited its power of regeneration. It followed, that the human organism possessed an inferior faculty of regeneration. Only a stump appeared in the place of a lost arm, leg, or even finger, a stump which bore no resemblance to the limb it replaced. It was thought that in the higher animals, and, consequently, in man, the faculty of regeneration was principally confined to the healing of wounds.

But here is what experiments showed.

At the Histological Laboratory of the Institute of Animal Morphology Professor Studitsky and his associates pared off hens' hip bones. The hens were crippled. They could not walk. But a new hip bone eventually began to grow in place of the excised one.

The faculty of growing a lost bone, particularly one of such dimensions as the hip bone, had never been previously observed in birds. Yet the experimenters saw it happen. The new hip bones were of the same size and thickness, and performed their function as well as the old. The crux of the matter was in the periosteum, which the experimenters left intact when paring off the hip bone.

The periosteum is a membrane of connective tissue which closely sheathes the bones like a thin outer covering. It was the periosteum, the scientists found, that grew and reproduced bone tissue.

Other experiments at the same Histological Laboratory showed that animals—rabbits and dogs, for example—could grow muscle as well as bone.

The muscle of a rabbit's calf was completely removed. The removed muscle was cut into pieces. This minced tissue was then implanted in place of the muscle. Soon a new muscle appeared, which was exactly like the one previously removed. The lost organ was regenerated. The animal ceased to be a cripple.

Professor Studitsky's research suggests that regeneration may some day help the higher animals, and man, to regain lost organs. Other highly interesting studies of regeneration in higher animals are also in progress. They include the research of Professor Khrushchov.

AGENTS OF GROWTH

KHRUSHCHOV PLACED tissue taken from a man in an artificial nutrient medium. It increased in size, and its cells multiplied. But soon its growth stopped. Then the professor added some white blood corpuscles to the nutrient and the cells of the tissue resumed their growth.

We are familiar with the properties of white blood corpuscles, or leucocytes. Mechnikov named them phagocytes, implying that they engulfed and digested foreign substances. Phagocytes protect the body from harmful intrusions.

It transpired, however, that leucocytes also promoted regeneration. Penetrating the walls of capillaries, leucocytes converge upon the wound, destroy germs, and secrete certain substances that promote healing and speedy formation of the scar; in other words, they promote the regeneration of cells. That is why Professor Khrushchov added white blood corpuscles to the nutrient.

Substances that promote growth are known as trephones. A wound washed or irrigated with blood serum rich in trephones, heals rapidly.

The data compiled by Khrushchov and other Soviet scientists illustrate the astounding acumen of Pirogov, the famous Russian surgeon who more than a hundred years ago asserted that the blood flooding the seat of a wound promoted healing.

In line with Pirogov's assertion, science today is well on its way to the discovery of ways and means—conditions and substances—promoting regeneration. To cause a wound is in itself to cause intensified regeneration. In the absence of a wound the regenerative faculty of tissues is dormant.

Morozov, a Soviet biologist, used the fluid constituent of rabbit's blood to prepare a nutrient medium for a piece of excised rabbit's liver. But the piece of liver did not grow. Its cells did not multiply. Their power of regeneration was negligible.

Morozov then took a second rabbit, and operated upon it. He cut off a bit of its liver. In performing this operation he took every care that the rabbit survived. After some time he used the fluid constituent of its blood to prepare a new nutrient, and placed the first piece of liver into it.

The picture changed. The liver tissue showed a marked growth. Its cells multiplied vigorously.

It was the nutrient that made all the difference. The second nutrient, in contrast to the first, was from the blood of an operated rabbit. Presumably, this rabbit's blood contained substances secreted by the cells of its liver when the latter was injured in the operation. These substances promoted the growth of the cells in the first bit of liver. They may, therefore, be regarded as trephones.

Research is still in its initial stages. But the results on hand show that regeneration may be promoted artificially. If science will find stimulants powerful enough to promote the regeneration of every kind of tissue, it will probably learn to reproduce lost human limbs.

For science that is not an impossible task. But it is still a matter of the relatively distant future.

PROPERTIES OF EMBRYONIC TISSUE

OTHER PROMISING ASPECTS in the problem of regenerating human organs are bound up with studies treating the embryonic state of living beings. Professor Popov and his associates at the Laboratory of Experimental Embryology of the Institute of Animal Morphology have made important discoveries.

The embryonic development of living matter begins with the division of the fecundated cell. The embryo, whose shape varies in all species, is the product of a ceaseless multiplication of cells. As time goes on the rudiments of future organs emerge from this homogenous mass of cells. This shows that embryonic tissue has no preconceived rudiments of organs. The appearance of the rudiments is bound up with the development of the embryo. The transformation of cells into rudiments of definite organs depends solely on the processes of embryonic development. The differentiation of the cells keeps pace with the stages of this development. Up to a certain point the cells are all alike.

But how is it that cells which are at first identical eventually form different organs? Isn't that a delusion? Perhaps the cells are really different in the initial, pre-rudimentary stage, though this fact escapes detection?

Experiments performed on frogs offered conclusive replies to these questions.

At a certain point in the life of a frog's embryo there emerges a layer of cells of the future skin—the rudiment of the skin. In the same way there appears what is known as the neural plate, or the rudiment of the nervous system. The researchers knew full well at what stage, and when, these rudiments make their appearance in a frog's embryo. They removed a bit of embryonic tissue from the site of the future neural plate just before the moment of its appearance, and transplanted it to the site of the skin-to-be.

And did the neural plate grow where skin should have been ? Nothing of the kind. In its new place the tissue that would normally have developed into a neural plate, became the rudiment of skin instead.

Another bit of tissue was similarly transplanted from the site of the future skin rudiment to the site of the future neural plate. In due time the transplanted tissue developed into the rudiment of the neural plate.

Repeated experiments on frogs, tritons and other amphibia produced the same results. More complicated tests also had a similar effect. In the triton's larva the layer of cells which was to develop into the eye lens was transplanted to the site of the future skin. The cells of the future eye lens turned into cells of the skin rudiment. Conversely, a slice of future skin placed on the site of the future eye lens developed into an eye lens.

This reveals an important fact. The leading part in the formation of organs does not belong to any intrinsic properties of cells. Organs form under the influence of those parts of an embryo which come into close contact with the tissue of the future rudiments, and constitute their immediate medium.

Regardless of its original place in the embryo, transplanted tissue develops into the rudiment which should normally emerge at the tissue's new site.

This conclusion suggests the most likely way of reproducing organs. Up to a point it is even possible to surmise the course of the operation. Embryonic tissue should be transplanted to that site of the animal or human body where the lacking organ should be, or where some part of this organ still remains. In regenerating lost organs, or parts of them use should be made of the faculty of the neighbouring organs to influence embryonic tissue and to make it develop into the organ whose place it occupies.

But all this gives rise to perfectly legitimate questions. What has the development of rudiments in embryos to do with organs lost by people through injuries or diseases in their childhood, adolescence or maturity? Could embryonic tissue transplanted to a stump help to restore a lost organ?

The researchers of the Institute of Animal Morphology hope to get positive answers to these questions. That, in effect, is the crux of Professor Popov's daring idea. It has its grounds. Experiments with mature frogs have been successful.

Their cornea was removed. A slice of skin from a frog larva, a tadpole, was attached in its place. The transplanted skin soon showed signs of change: it thinned out, became brighter and turned transparent. In the end it lost the appearance of skin and became an ordinary cornea.

But this was true only if the skin was taken from a tadpole before it became a frog, and if it was transplanted to a fully matured specimen. Such were the main features of the experiments. Experimental thought carried on. Its final goal was man.

Frogs and tritons are comparatively simple organisms. It was high time to try similar experiments with higher animals; rats, for instance. They were mature rats. A bit of skin was substituted for their excised cornea; for greater certainty the rats' eyelids were sewn up for several days after the operation. The transplanted skin was taken from rat embryos extracted on the fourteenth or fifteenth day of pregnancy, or three or four days before birth.

Not all the experiments succeeded. In just one of every three or four rats did the transplanted embryonic skin finally become a cornea. But it showed that the researchers were on the right track.

The new regeneration method may benefit from a preliminary conservation of the embryonic skin. Bednyakova, one of Professor Popov's associates, proposes to immerse the skin in blood serum at a temperature of 39^0—42^0 F. In this condition, tests showed, it keeps a long time without losing its properties. Supplies of skin for transplantation may, therefore, be on hand at all times and in any quantity. This will, no doubt, be of great help in further research.

It is a far cry from experiments with rats to operations on human patients. But once science masters the laws of development and regeneration it will unquestionably solve the problem. The day is likely to come when the reproduction of organs by means of transplanted embryonic tissue will become a commonplace operation.

But that is for the future to decide. In our day damage to a man's organs and loss of tissue may, with only few exceptions, be remedied in just one way—the surgical way.

That is the business of plastic surgery.

THE AFTEREFFECTS

The Great Patriotic War called for a tremendous effort. And Soviet medicine passed muster honourably. The self-devotion of the medical personnel, and the excellent equipment at their disposal, helped to preserve the lives of millions of fighting men.

But in many of the healed the aftereffects of wounds could not be eliminated. Large scars remained after serious wounds or burns. The scars contracted the underlying muscles, and this often led to distortions, or contractures, of the trunk or limbs. Bone fractures resulted frequently in a shortening of legs or arms. The victims were unable to walk without the help of crutches, or a stick. A shortened arm was a handicap in work.

If the human body had the same faculty of regeneration as the triton, all this would not happen. The surgeon would then remove the shattered fragments of bone or muscle, and what remained of the leg would give growth to as much tissue as would be required to form a normal new limb. Contractures and shortenings of limbs would be unknown.

But the regenerative powers of the human organism confine themselves chiefly to connective tissues, and that produces nothing more than a scar.

In a great many cases, however, plastic surgery comes to man's aid, saving him from incapacitation.

One day a patient with a long since healed leg fracture came to a Leningrad hospital. His leg was seven inches shorter than normal. A bony growth projected from the bone at the point of the fracture. The patient walked on crutches. Two improperly knit and shortened halves remained instead of the hip-bone. A part of the bone, reduced to fragments, had been extracted during the bone-setting operation.

The knit parts of the bone had to be disjoined and a bone plate taken from some other limb inserted between them. But a seven-inch-long bone plate was not all. The hip had to be strong enough to bear the weight of its owner, and a transplanted bone fragment could scarcely be expected to possess such strength.

So the doctors decided to lengthen the leg to its natural length without implanting a bone fragment. Professor Bogoraz, a prominent Soviet surgeon, had proposed a most original method, and they were going to try it on their patient. It was an operation known as segmental osteotomy.

The improperly knit shortened bone is cut into oblique segments—two in the case of the top section of the broken bone, and two in the case of the other. If one of the sections is longer than the other, it may be cut into three segments. The doctors then use a special device to draw out the leg gradually to its normal length. The segments of the bone are pulled apart by the muscles, their oblique surfaces gliding one along the other. The upper end of one segment forms a continuation of the other's bottom end, forming a continuous chain of bone segments. A bony growth forms at their points of contact, joining them together for good.

An operation of this kind was performed on the patient, and a month later he was discharged from hospital. His gait was firm. He left his crutches behind in the clinic.

TRANSPARENT CAP

PROFESSOR BOGORAZ'S OPERATION is simple and ingenuous. It involves only the bones of the affected limb itself. The surgeon's work is made easier.

Sometimes a person is either totally incapacitated or perambulates with the greatest difficulty, because his leg loses its mobility. Cases of this kind often occur as a result of tubercular affections of the hip joint.

The hip joint consists of a cup-shaped socket and the head of the thigh bone, which fits into the socket. Tuberculous germs infest the tissues of the joint and gradually destroy the head of the thigh bone. Morbid changes also take place in the socket. At first there is an inflammatory exudate. Then scars appear, which seal up the joint, and it loses its mobility.

In the past surgeons knew no way of remedying the matter. But science found a way. The joint is dissected, and the adhesions, and the useless part of the head, are removed. The excised part is replaced with a sound bone taken from a corpse.

But this method has its drawbacks. Firstly, the operation is not always successful. Secondly, the tuberculous infection may spread to the new bone.

Under the circumstances the excised part of the bone were better replaced with a graft made of a material immune to the action of microbes and just as durable as bone. Surgeons found such a material. It is an organic compound, known as plexiglass, available in flat sheets. It is much like ordinary glass for its transparency, and somewhat lighter in weight. Furthermore, it is highly durable. It is used in armour-plating aircraft, and the vision slits in tanks are made from it. Plexiglass may be sawed, ground and polished to any desired shape. Boiling does not harm it, and sixty minutes in boiling water make it sterile.

Soviet surgeons were struck by the merits of plexiglass. A large number of experiments showed that it was splendidly suited for medical purposes. It could be used, for instance, in plastic surgery of the nose, or as a substitute for defective sections of bone removed from the skull.

In 1948 *Khirurgiya* (*Surgery*), a Soviet medical journal, published an extremely interesting article by Professor Dikhno, of Khabarovsk. It describes an operation involving the use of plexiglass.

A 17-year-old youth was unable to walk because his right leg, folded up to his stomach, could not be straightened. Tuberculosis of the hip joint had made a cripple of the boy, and though the disease had subsided, it had done irremediable damage.

Professor Dikhno operated on the youth. He opened the hip joint and found bone adhesions of the hip and pelvis. The socket of the joint was severely damaged by tuberculosis. The head of the femur, partially destroyed by the disease, had lost its normal shape.

The professor removed the bone adhesions and scars. He also extracted the affected parts of the bones. In place of the former socket the professor fashioned a new one. He then peeled off the affected coating of the head of the femur, causing it to become much thinner. That was sad, since the head was no longer solid enough to support the weight of the trunk. Moreover, it was too small for the newlyscooped socket. But Professor Dikhno enlarged it to the desired size. He put a plexiglass cap on it. The cap was an exact fit.

A month later the operated leg was back to normal. It bent and extended readily. The patient was able to walk.

RESTORED AVENUE

A MINE SPLINTER STRUCK the sergeant's left arm. The pain made him lose consciousness. He regained it only at the battalion's field hospital. A rubber tourniquet applied in the firing line, was twisted round his left arm in the armpit.

The wounded man was put under an anaesthetic and heard nothing of what the doctors were saying. They had bared the wound and discussed what they should do—amputate, or try to save the arm in spite of everything.

They chose the latter course, and removed the mangled muscles and bone splinters. Then they sprinkled the wound with an antiseptic (streptocid) to prevent infection, and sutured it.

That was in 1944.

After the war the sergeant returned to his native Leningrad, but was unable to work in his former job of fitter. He was a cripple. The arm was there, but the hand hung limply at his side. The radial nerve was not only torn by the mine splinter, but had lost more than an inch of its fibres. There was a gap between the ends of the torn nerve trunk. The nerves of the hand had no connections with the central nervous system, and the wrist and fingers could scarcely move.

But in 1946 his hand was returned to normal. He could do any kind of work. If it were not for the deep shoulder scar visible whenever he rolled up the sleeve of his shirt, there would be no sign of the recent traumatic paralysis of his wrist and fingers. The inch-long breach in the radial nerve trunk, which had cut off all nerve impulses to and from the hand, was bridged by a link of nerve tissue.

It had been a complicated operation. A few years ago it would have appeared impossible. But Soviet scientists paved the way for it. Professor Anokhin's research was particularly valuable. The professor worked out a way of restoring disconnected nerve lines. He also found the most suitable substitute for lost nerve fibres—the nerves of a calf.

Excised strips of a calf's nerve trunks are conserved in formalin. Before the operation the formalin is carefully washed off to avoid irritations of the living tissue. A strip of calf nerve of the desired length is inserted between the disjoined ends of the damaged nerve trunk, forming a kind of bridge.

The part of the radial nerve leading from the lesion to the brain had not lost its vitality, while the part leading from the lesion to the fingers withdrew from the nerve processes. It was dead, as it were. In other words, the transplanted strip of calf's nerve formed a bridge between a living and a dead nerve. They could hardly be expected to perform a common function, especially if they were joined by a formalized bridge which could not be regarded as living tissue.

But they did. The nerves of the hand, from forearm to finger tip, resumed their function. They regained their faculty of causing the muscles to contract, and the fingers regained their mobility. That was indeed amazing, but it was no miracle. Physiology has an explanation for it.

The transplanted nerve link creates the desired conditions for the regeneration of nerve tissue. The part of the nerve trunk which is connected with the brain—the living part—regenerates. Its fibres show growth. They begin an imperceptible advance across the bridge of transplanted tissue, cross the bridge and creep slowly along the old trunk on their way to the incapacitated muscles of the wrist and fingers. The paralyzed part of the limb regains its faculty of receiving nerve impulses, and consequently regains its mobility.

The fibres take months to reach their destination. Life is slow to return to the almost motionless wrist. At long last it reaches the fingers. They begin to stir.

An operation of this kind was performed on the sergeant's arm.

ITINERANT SKIN

PHYSICAL DISFIGUREMENT weighs heavily on the mind. Particularly if it affects the face. It may be that the mouth was torn, the lips mangled, or part of the teeth and gums, or the nose, were destroyed beyond recognition. Ugly scars remain after the wound heals.

But apart from the mental anguish that it causes, this disfigurement often interferes with such vital functions as the taking of food, or with speech.

The disfigurement is best concealed under a layer of transplanted skin. If the scars are already there, they are cut away to make room for the graft. But where to take the skin for the transplantation? Taking it from the face itself would be most convenient, but it would only mean a new scar. The larger the disfigurement, the more undesirable that would be, for it would involve a substantial strip of skin. It must therefore be taken from somewhere else, some place where the new scar would be less conspicuous; the neck, perhaps, or the arm, leg or abdomen. But skin taken from there would perish before it has time to take root, and would wither away due to a lack of nutrition.

But it would be quite a different story if, on the one hand, the skin were taken from a distant and unconspicuous place, and, on the other, if it were not altogether severed from the body and the vessels during the process of transplantation.

It may not seem feasible at first glance, but Soviet doctors found a way which met both these requirements. By their method the skin may be taken from almost any part of the body and transferred to any other part without the danger of necrosis. The most remarkable thing about it is that the bit of skin makes the trip from its natural site to the site of the operation all on its own.

In spite of his young age a twenty-year-old railway worker was stricken with an ailment oftener met in older men. It was varicose veins of the hip. Varicose means swollen, or enlarged, like a pouch. Varicose veins have a tendency to ulceration. The youth was brought to the clinic with complications caused by an operation he had had three years before. On that occasion a section of the enlarged vein was removed from the right hip and knee. It had been expertly done, but the post-operative wound did not heal. A large, incurable ulcer appeared. It was this ulcer that brought the railwayman to the clinic.

The doctors saw plainly that the usual treatment would be useless in his case. The unhealing scar and the ulcer had to be cut out, and the resultant wound closed with fresh, transplanted skin. The scar was a sizable one, and the skin graft would have to be large too. It could be taken from the other leg. But that leg's veins were also varicose; not to the same degree as the first, but bad enough to affect the proper nutrition of the skin. The transplantation would be pointless, for bad nutrition of the skin was likely to cause a new ulcer. So the doctors turned their attention to the patient's back.

They picked a section of skin near the shoulder-blades. It was a rectangle about 5 inches long and 2 inches wide. But the skin was not cut out. It was incised along the two long sides of the rectangle. A thin surgical knife was used to pare it off, and separate it from the underlying tissue. A flap of skin was thus produced, which was connected with the body by its two unincised edges—the short sides of the rectangle.

The surgeon took a needle and silk thread. He folded the two incised edges inward and sewed them together, obtaining a miniature cylinder which was much like the round grip of a suitcase. Sewed up in this way the bleeding inner surface of the flap of skin was protected against infection.

The skin flap did not necrose. Nutrition reached it by the unsevered blood vessels of the two unincised edges of the rectangle.

An incision along one of these edges detached the oblong roll of skin from the body. It no longer resembled a suitcase grip, and took on the appearance of a rounded, pliant stalk, easily bent in any direction. The stalk was ready to start on its journey.

The length of the stalk was measured off along the patient's back in the direction of the affected leg, and an incision made there. The top of the stalk was then bent over, fitted into the incision, and secured in it. In several days it took root. The stalk again took the shape of a suitcase grip, but this time the "grip" was its own length nearer to the leg.

That was how the flap of skin made its first 5-inch step. There was no danger of necrosis. The skin was fed as before through the foot of the stalk. Meanwhile new blood vessels advanced into it from the incision in which its top was secured. The "grip" soon got its nutrition from both ends, and the danger of necrosis became even more remote.

After some time the skin flap was able to make its second step. The second short edge of the rectangle was detached from the body, and made something of a cart-wheel to arrive at a new incision prepared for it another length away.

Advancing in this manner along the route mapped out for it by the surgeon, the skin made its journey from the shoulder-blade to the hip, and on to the right knee. Its free end was stitched into the incision made just above the edge of the ulcerated site.

The skin flap had thus reached its destination. That was the final stage of its journey as a "suitcase grip." Now for the final stage of the operation. The farther end of the "grip" was cut off. The stalk-like skin roll stood rooted in the incision on the ulcer border. The sutured side was then incised, and the "stalk" unrolled into a rectangle again. The ulcerating scar on the operation site had been removed and there was a wound in its place. The spread out "stalk" was placed upon it. The new skin took its designated place, and sutures secured it for good. The transplantation was over. The wound on the patient's back, where the skin was originally taken, had healed by the time.

The surgeon who thought of this method is to be congratulated. Thanks to him surgery can offer relief to the halt and the suffering. But the operation has one shortcoming. It takes too long. Along the graft's journey to its destination its ends have to be sewn into the skin alternately many times. And every time the patient must wait until they take root. Sometimes complications set in during this drawn-out procedure.

Something had to be done to shorten the operation. The "stalk" had travelled on foot, as it were, length by length. The progress of the "pedestrian" could be speeded by a conveyance of some sort. And the surgeons commandeered one. It was the arm.

The grip-like skin graft was first transferred from the back to the belly. This was comparatively easy. Besides, in most cases it could be taken directly from the belly itself. From there one end of the "grip" was transplanted to the arm—usually close to the wrist. As soon as this end took root, and its blood supply was secure, the foot of the "grip" was detached from the belly. The arm could now convey the stalk directly to the seat of the operation—shin, cheek, nose, or most any other part of the body. The stalk's journey was thus substantially shortened. The operation became simpler, and the danger of complications more remote.

Today both the initial and improved forms of the operation are known throughout the world as the walking stalk operation. It was evolved by Academician Filatov, the Russian oculist.

A NEW TONGUE

During the fierce fighting of August 1943 a wounded soldier, Pyotr Sigayev, was brought to a field hospital. His life was in no danger, but the shrapnel wound caused great concern.

His head was a gruesome sight. Half his face was mutilated beyond recognition. The lower jaw was fractured in two places. All but four of his teeth were missing. Unintelligible sounds came from his lips. Sigayev's tongue was crushed. Mere rags of tissue remained in its place, and had to be cut out to the root at once under novocain anaesthesia.

The patient was evacuated to Moscow. By the time he arrived at the Central Institute of Traumatology his condition had deteriorated. The tongueless man could not talk. What was worse, he could hardly chew or swallow. He took food in very small quantities, and then only lying down.

At the institute the surgeons first tackled his shattered jaw. A month later, after the patient was somewhat fortified by artificial feeding, they risked an operation: all scars and adhesions in the vicinity of the fracture were cut, the jaw pulled forward to its normal position, and put in a plaster cast for six weeks.

After the lower jaw healed artificial dentures were attached to the four remaining teeth. This facilitated chewing. The splinters of the lower jaw were removed and the bone defects made up by a transplanted cartilage. Another cartilage graft helped to shape the chin.

There now remained the tongue. The only possible thing to do was to make a new one. The most suitable material for it was the skin; but a very large piece of it was required. It was to be taken from the patient's back. A round Filatov stalk was prepared under the shoulder-blade. But the skin alone was too thin to suit the purpose. The subcutaneous tissue and a layer of fat would have to go with it. That would make the stalk thick enough.

The graft was to take the shortest possible route to its destination. Transferred from the back to the belly, it was further transplanted to the arm. The patient had only to raise his arm to bring the stalk to his mouth.

The operation was completed in November 1946. The root of the tongue was sutured with silk thread and drawn out as far as it would go. Operating in the depth of the oral cavity was extremely difficult. The surgeons removed the scars from the surface of the tongue stump. The site was then ready to receive the Filatov stalk.

The end of the stalk was unrolled and inserted into the oral cavity, where it was sewed on to the upper and lower surface of the tongue root. Now one end of the stalk was implanted in the root, and the other remained on the arm. A special supplementary plastic denture was inserted between the patient's teeth to prevent him from biting the stalk.

For three weeks Sigayev's arm remained pressed to his mouth. To hold it in that position it was bandaged to the head. Surgeons kept constant vigil over their patient. All went well. The stalk took root. It was finally cut away three inches from the root. The smaller part of it remained on the arm, and was soon removed; the second part was in the mouth, grown firmly to the root, which had retained its original muscles. That was how a new tongue was made.

In two weeks Sigayev was mute no longer. His speech was perfectly intelligible. He breakfasted, lunched, and supped like all healthy people.

Sigayev took delight in showing his new tongue to the other inmates of the ward. There was general joy over it. It was practically as good as the old one.

This delicate operation, skilfully performed by Professor Mikhelson, was another triumph of Soviet plastic surgery.

CLOSED PATH

THERE WAS A MISHAP in our house. Little Tolya from the flat next door had swallowed some caustic alkali. The doctor was summoned at once, and took steps to neutralize the poison. But it had done its harm. Tolya's gullet was badly burnt, and he had to go to hospital. The mucous membrane of his gullet, or oesophagus, was a festering wound. He could not eat.

But without food the boy would die, and so he had a gastrostomy. An opening was made in the abdomen and stomach. A rubber tube was inserted into it, and liquid or finely granulated foods were poured through it into the stomach with the help of a little funnel at its external end.

In cases of acid or caustic alkali burns of the oesophagus the outcome is often very sad. Scars appear in place of the destroyed tissue. They gradually thicken, contract, and constrict the oesophagus. If the constriction is small the patient can still take food, particularly liquid food. But in substantial constrictions the gullet does not even let through liquids. The patient must then be fed through the opening in his abdomen for the rest of his life.

Such was the unhappy fate in store for Tolya.

There is another cause that makes the oesophagus impassable.

In my school days I had a friend named Sasha. One day I had dinner at his place. All his family were at the table. When the roast was served Sasha's father pushed his plate away, and said in bewilderment:

"I can't understand it. The food sticks in my throat."

A bit later he tried to resume his meal. But after two or three mouthfuls he said with alarm:

"Funny! It's worse today."

A week later I met Sasha hurrying down the street. There was concern in his face. He said he was going to visit his father, who was in hospital. I learned that Sasha's father had cancer of the oesophagus, that an opening had been made in his stomach, and that he was fed through a tube. The alternative was death from starvation, because the tumour had made swallowing impossible.

Sasha's father was kept alive in that manner for two months. Nothing else could be done to help him. The cancer spread further, and he died.

HORNS OF A DILEMMA

OPERATING ON THE GULLET is very difficult. The greater part of the gullet lies behind the breastbone between the lungs with the pleura, near the heart and adjoining the posterior mediastinum—the rear part of the chest partition. It is in the immediate neighbourhood of vitally important organs and vessels. An inadvertent injury to one of them means fatal haemorrhage. Infection means almost certain death.

That is why the doctors could do nothing in Sasha's father's case. It was thought impossible at the time. Besides, an operation for gullet constriction was not just a matter of removing a section of the gullet. In view of the swellings and scar strictures so much of the gullet would have to be removed that it would not be possible to restore its function. What would remain of it would be a gullet no longer. The patient would require a new one. But in that day surgeons were unable to make artificial gullets. All they could do was to cut the opening in the abdomen and stomach, produce a fistula, and feed the patient through a rubber tube.

The rubber tube averted death from starvation. But it was hardly a pleasant thing for the patient, and turned him into an invalid.

The medical progress in the 19th and, notably, the 20th centuries led surgery up to the problem of gullet operations. In 1904 papers appeared asserting the feasibility of artificial gullets. One of the first to perform an operation of this kind was the Russian surgeon, Professor Herzen. That was in 1908. But the greatest contribution to the solution of the problem was made by surgeons of the Sklifosovsky Institute in Moscow in Soviet time.

SURGICAL DETOUR

THE SKLIFOSOVSKY INSTITUTE took in a new patient. He was nineteen years old and came from Sverdlovsk. Seven years previously the boy had swallowed some crude hydrochloric acid, which he mistook for water.

The gullet stricture developed slowly but surely. To avert a total stricture doctors tried passing bougies, or special bulbous instruments, which were meant to dilate it. But that was of little help. The youth had to be fed through a stomach fistula. The doctors in Sverdlovsk tried to render more effective help and create a new gullet. But the operation was unsuccessful.

At the Sklifosovsky Institute Professor Petrov examined the youth with utmost care. There were scars—marks of a surgeon's knife—on the patient's chest and neck.

A few days later the youth was put on the operating table. The surgeon opened up the abdominal cavity and drew out about 12 inches of the small intestine. He cut it at both ends with true surgical precision, detaching it from the bowels. Then he joined the two open ends of the bowels and thereby restored their continuity.

The excised piece of the small intestine had not lost all its connections with the bowels. Some blood vessels led to it from the mesentery. The mesentery comprises tissues that invest the intestines and connect them with the dorsal wall of the abdominal cavity. It serves to retain the organs in position, and to support and convey to them the blood vessels.

If the vessels had been cut, the excised section of the intestine would be deprived of its blood supply and would soon perish.

The surgeon made a special tunnel-like passage under the skin of the chest. With the help of instruments specially designed at the Institute, he detached the skin from the underlying tissue all the way from the cut in the abdomen to the left collar-bone and the neck. This formed a subcutaneous tunnel. The excised intestine was carefully drawn into this tunnel. The tunnel was like a casing for it. One end of the intestine came to the surface on the neck, in line with the upper section of the gullet.

The operation entered its second, no less important stage. The surgeon cut open the neck, bared the gullet, and drew it out. He sutured the intestine into an opening in the wall of the gullet above the stricture.

So much for the top end of the excised intestine. The bottom end, meanwhile, had been previously sewed into the stomach below the stricture. The excised section of the small intestine thus connected the topmost part of the gullet with the stomach. It became a regular gullet itself.

The operation on the youth was made in 1942. Before and after it Professors Petrov, Arapov, Rozanov, and others, of the Sklifosovsky Institute, performed hundreds of similar operations. A great many operations of this kind were since performed in other cities of the Soviet Union. The methods evolved by the Soviet surgeons turned out to be the most effective of all those previously tried. They yielded the best results. They often made the rubber tube and fistula superfluous.

But the surgeons were not entirely satisfied. The same Sklifosovsky Institute which had shown a particular interest in artificial gullets, felt the need for further improvements. Its surgeons studied the operation in minutest detail. The remarkable surgical technique they had evolved and the ingenuous surgical instruments they had designed, made their work easier. At long last they hit upon the brilliant idea of compressing the arteries at the root of the mesentery, farther away from the intestine. This seemingly minor detail secured an ample blood supply for the excised section of the intestine, improving the chances of success.

But there still remained food for thought. Each new achievement was a stepping stone to fresh achievements. There was one aspect of the operation which, among other things, gave the surgeons no rest. It was the mental effect the operation had on the patient.

The new gullet performed its function perfectly. The rubber tube and fistula, which so depressed the patient, were done away with. But the operation left scars on the neck, ugly scars and deformities which marred the patient's appearance. That was far from unimportant to a person's state of mind. Accidents causing gullet strictures involve mostly children and adolescents. Years go by and the children grow up. The operation that had saved them, leaves behind tell-tale marks. This physical handicap naturally weighs heavily on the minds of young people.

The concern Soviet surgeons felt for the destiny of their young patients led them to the desired goal.

In the winter of 1947 a 22-year-old chemistry student was brought to Professor Rozanov's operating room at the Sklifosovsky Institute. She had a stomach fistula. But now the girl was to get an artificial gullet.

The surgeon began the operation. He performed it in a manner that he had long since worked out on numerous animal subjects.

Six weeks later the girl was discharged from hospital. She beamed with happiness. The rubber tube was discarded for good. There were no disfiguring marks on the neck. The artificial gullet ran alongside the now useless old gullet along its natural course inside the chest.

It was an operation of high precision and exceptional skill. The surgeon was up against formidable difficulties. The perils of operating on the chest, which holds the vitally important organs of the body in such close proximity to each other, cannot be exaggerated. It was all a matter of immaculately accurate calculation, foresight, and a novel method of anaesthesia. The success was striking.

One end of the excised intestine was sewed into the stomach. But there was no subcutaneous tunnel across the chest. Instead an opening was made in the diaphragm, which gave the second, free end of the intestine access to the chest cavity. The surgeon then carefully found the gullet and bared it of its surrounding tissue. The stricture that had made the gullet impassable was spotted in its upper part. The intestine was drawn up to a spot above the stricture, and its free end sewn into an opening made in the gullet wall. The transplanted intestine thus took its place alongside the gullet in the immediate proximity of the other thoracic organs—lungs, heart and the major arteries and veins. The operation ended after sutures were placed on the diaphragm.

The stomach wound healed, and soon only a small scar remained as a reminder of it. There was nothing in the patient's appearance to distinguish her from other people. The operation was a success. What is more, it involved less risk than the previous operations, in which the artificial gullet was laid along a subcutaneous tunnel.

Subsequent operations, even the more difficult operations for cancer of the oesophagus, were often crowned with the same remarkable success, and lent added weight to the bold solution proposed by the surgeons of the Sklifosovsky Institute.

Many other names deserve mention in the field of plastic surgery. There are Professor Savinikh, of Tomsk, Professor Kazansky, of Moscow, Petrovsky, of the Institute of Experimental and Clinical Surgery, and the Professors Savitsky and Melnikov, who have saved countless lives with their original operations for cancer in the lower sections of the gullet.

BRIEF SUMMARY

We have dealt with only a few of the achievements of modern plastic surgery. They are enough to give an idea of the contribution of Soviet scientists to this branch of medicine.

To a certain extent plastic surgery makes up for the human lack of the faculty of regeneration. Modern medicine makes bold use of the laws of nature and performs the seemingly impossible.

Soviet surgeons have their triumphs in this branch of medicine as well. A device for suturing blood vessels is an achievement of recent years, proposed by a group of designers and surgeons of the Sklifosovsky

Institute: engineer Gudov, the surgeons Androsov and Akhalaya, and others. This device not only simplifies and improves the difficult operation of making an artificial gullet, the surgical treatment of angina pectoris and all the other major operations, but brings nearer the prospect of transplanting entire limbs and even vitally important internal organs.

Let us recall with what remarkable insight Pirogov said about a century ago: "Surgery would enter upon a new era if it could only find a way of joining blood vessels quickly and securely." This new era has come for Soviet surgery. It holds great prospects for medicine.

In June-July 1950 the Joint Session of the Academy of Science of the U.S.S.R. and the Academy of Medical Science of the U.S.S.R., which was devoted to the development of the teaching of Pavlov, showed what new horizons open to sugery with the study of the great physiologist's ideas. Pavlov's view of the organism as a single whole is of the utmost importance to surgery. An operated organ is not an isolated part of the body. It is an integral part of a whole, governed by the central nervous system. This idea, known as the idea of nervism, emphasizes the functional significance for the entire organism of the particular organ undergoing an operation. It stresses the importance of the patient's post-operative condition and of the outer environment, and calls for a study of the possible reflex reaction to an intervention restoring the normal functions of an organ.

Soviet doctors, who work under the exceptionally favourable conditions provided for scientists in the U.S.S.R., have achieved brilliant results in the most difficult fields of surgery—thoracic surgery, and surgery of the heart, oesophagus, and the central and peripheral nervous systems.

CHAPTER FIVE

THE HEART BESIEGED

STABBED IN THE HEART

SIXTEENTH-CENTURY medical annals describe the strange case of the duelist who, wounded in the chest, counter-attacked his adversary with such unexampled fury that the latter took to flight. The wounded pursued him almost 200 steps before collapsing. When Ambroise Paré, the noted surgeon who attended the duel, came running to his side, the man was dead.

The surgeon was dumbfounded. He was surprised by the two hundred steps of a man fatally wounded in the heart. If Paré had not seen it with his own eyes, he would never have believed it possible. In his day a stab in the heart was thought to cause instantaneous death.

But the case described by Müller, another doctor, almost a hundred years later, was even more astonishing. His patient—a wealthy man whose fortune drew a flock of relatives and friends to his bedside in the hope of a rich inheritance—lived fifteen days after being stabbed in the heart with a dagger. The relatives were impatient and disappointed. The doctor was struck with wonder. His case upset everything known to contemporary medicine.

To the great, though disguised joy of his relatives the man died on the following, sixteenth day.

But doctors would have been no less surprised if he had lived fifteen decades. They were puzzled why death had not come right after the heart wound.

A WORD ABOUT HEARTS

PUT YOUR HAND TO THE CHEST and feel your heart beating. It never stops. Not even for a minute. It carries on and on, driving the blood through the arteries and veins. And should it stop beating, life would end too. The brain would be the first to fail, followed by the other organs of the body. An impenetrable partition divides the heart into two halves—sometimes called the right and left hearts. The auricle and ventricle of each half communicate by means of an opening. Blood from the lungs enters the heart through the left auricle, and is forced out of it into the aorta through the left ventricle. Spent, venous blood, meanwhile, reaches the heart through the right auricle, and the right ventricle eventually ejects it into the pulmonary vessels for oxidation.

The heart itself requires a large amount of blood to nourish it. This blood enters the heart vessels through the initial portion of the aorta. The heart cannot work without blood. An unfailing and continuous supply of blood is absolutely essential for heart activity.

The heart is enveloped in a fairly thick serous sac—the pericardium.

EMPTY DREAM

ALL THE BLOOD IN A HUMAN organism passes through the heart every 23 seconds. The heart ejects the blood into the aorta with vigorous pushes. A wounded heart also does that. But every time it contracts part of the blood pours out of the wound. This blood does not reach the aorta and vessels and, consequently, no longer returns to the heart.

Each minute the heart makes 70 to 80 beats. A wounded heart loses blood with every one of them. If the wound is large, the heart may lose all its blood within a minute or two, and if it is small, within five to ten minutes.

A heart wound inevitably results in death within the first few minutes after it is inflicted. That, at least, was the general opinion. And that was why Ambroise Paré's surprise was quite legitimate.

The doctor who treated the patient fifteen days after the latter was stabbed in the heart, was also an experienced physician. Since the patient was alive when he was summoned to him, he should have thought of operating—of sewing up the heart wound. But he did not.

Firstly, in his day people had no idea of heart operations. Secondly, doctors would never have braved the perils an operation of that kind involved, for their patients would have unquestionably died of what was then called gangrene and we now call blood poisoning.

Medicine had no idea of germs and bacteria at the time.

The duel we spoke of took place in 1563, and the case of the man who survived a heart wound for fifteen days, in 1641. Both cases occurred long before the first microscope, which discovered the world of microbes. But even if microbes had been known in the 16th and 17th centuries, that would not have changed anything, for at the time people knew nothing of how to combat them. The first intimation of how to fight disease-carrying germs in surgery, appeared as late as the 19th century.

What with his limited knowledge of that day, man did not even suspect the possibility of operating on the heart. Operations were performed almost solely on the hands, arms, and legs, and on the surface of the body. To operate on the chest or abdominal cavity, and especially on the brain, was then no more than an empty dream.

ONE OUT OF TEN

NOT MORE THAN A YEAR after the case of the man who lived fifteen days with a heart wound, another, even more astounding occurrence came to hand.

This time the victim of a heart wound recovered. He got well and lived on and on, as though his heart had never been damaged. There is no precise indication how long he lived, but it was years, in any case.

The physicians were mystified. They could not explain why the bleeding stopped. They were puzzled by the fact that the wounded heart ceased to lose blood during its contractions. But one thing was beyond doubt: the heart wound had healed of itself. Scar tissue had closed up the opening in the heart muscle. This could only have occurred if a clot of coagulated blood had first stopped up the wound. That was certain. But the question arose why this had never happened before, and what had hindered the formation of such a clot in other similar cases.

All this was cleared up in 1761 when doctors determined that victims of heart wounds did not die of blood losses so much as of the accumulation of blood in the pericardium, which, saturated with it, pressed upon the heart and brought it to a standstill. Death set in before the heart wound was given a chance to heal.

Here is the precise manner in which the heart stoppage comes about: the blood from the heart pours out of the wound into the pericardium, and dilates it. The tissues of the sac are copiously supplied with sensory nerve endings, which, irritated by the dilatation, cause intense excitement. Their impulses are transmitted to the brain—to that part of it known as the spinal bulb. From here the excitation is communicated to the vagus, whose filaments spread into the heart. The vagus is a nerve of inhibition. When activated, it inhibits the heart muscle. Vigorous inhibition results in a full stoppage of heart contractions.

Yet the fact remains that a man recovered from a heart wound. In 1642 that was an eighth wonder. But wonder or no wonder, even one such fact was of extreme importance to science. Plainly, death from a heart wound was not inevitable. From time to time new facts came to hand about people who survived heart wounds.

Medicine launched upon a search of means to facilitate the timely formation of a scar in the heart wound. The leading surgeons of the early 19th century elaborated a method which chiefly involved rest, ice, and blood-letting.

Rest was essential to protect the injured heart from undue strain. Cold facilitated the speediest formation of a blood clot. Blood-letting weakened the heart contractions. The weaker the heart beats, the less blood poured from the heart wound, and the less the obstruction to coagulation and clot formation. If unconsciousness was produced by the blood-letting, it was all for the best. During a faint the heart beat slowly, and that only facilitated the formation of a clot.

For its day this treatment was a step in the right direction. It achieved its purpose to a certain extent. Doctors no longer stood helplessly at the bedside of patients wounded in the heart. But it was a passive, a wait-and-see kind of treatment.

When notes were compared in 1868 they mirrored a certain amount of success. There were data on 401 heart wound cases. Of these forty-two, or ten per cent, recovered.

The figure may appear small, but considering that formerly all the wounded died, it was an improvement. However, doctors could not rest on their laurels when only one of every ten patients recovered. The wait-and-see method was not effective enough.

GRAVE OBSTACLE

ALMOST THREE HUNDRED YEARS passed since the duel. But the heart remained as inaccessible to surgeons as before. Nor was there any lack of interest in the heart. But a formidable obstacle—blood poisoning—stood in the way of all surgical progress.

Every doctor knew that a mere incision, a cut in the muscles, even a cut in the skin, would turn into a festering wound within a few days. The smell of rotting flesh augured the sad and inevitable end. A strong man could die of an insignificant operation in three or four days. In the early 19th century in Munich, for instance, eight out of every ten operations on the legs, arms, and hands, had lethal outcomes.

Whenever fragments of bone had to be extracted in fractures it was almost tantamount to a death warrant. Even in comparatively minor operations, such as lancing a boil on the finger, an angry red streak often crept up the arm under the skin, causing the shoulder to swell. It was soon apparent that it was blood poisoning and gangrene.

Consequences of this kind made even operations on the arms and legs extremely perilous, to say nothing of the lungs, stomach, liver, kidneys, and heart. To open up the abdominal or chest cavity was tantamount to murder.

BIRTH OF ANTISEPTICS

IN 1841 A THIRTY-YEAR-OLD professor, Pirogov, was transferred to the Petersburg Surgical Academy from Yuriyev.

He fitted out a new ward at his hospital. It was for patients with post-operative symptoms of gangrene.

This isolation of gangrene cases surprised the other surgeons. It made no difference, they thought, where these people with their inflamed and poisoned wounds would lie—separately, or in the general wards.

They saw no point to Pirogov's innovation. Microbes as disease-carrying agents were unknown then. The secret of post-operative infections had not yet been discovered. But everything Pirogov did and saw led him to the right solution.

He knew hospital gangrene to be the most terrible scourge of the wounded and ailing. He suffered a bitter sense of impotence when symptoms of infection marred the effect of brilliantly performed operations.

Pirogov worked day and night to get to the bottom of the complications. For days on end he studied the course of gangrene from the first moment it appeared. He visited the mortuary and made autopsies on countless corpses. He performed hundreds of experimental operations on animals. Years passed in untiring labour. His persistence was kept alive by a sense of the importance of what he was doing.

Then came the day when he glimpsed his goal. He arrived at the conclusion that gangrene was caused by unseen living agents. It became clear to him why the pathogenic process was almost imperceptible at first, and why it grew relentlessly to affect more and more tissues. Since the agent was living, it could develop and spread.

Pirogov's *Elements of Field Surgery*, which appeared in 1863, laid the groundwork of a new science—military field surgery—and contained a world of profound ideas aimed at relieving people from suffering. The book made direct allusions to the agents of hospital gangrene, describing them as "something organic capable of developing and spreading."

Having convinced himself of the causes of wound poisoning, Pirogov looked for means to combat them. He was aware from the first that the "miasma," as the invisible source of gangrene was called, could pass from a man with a poisoned wound to a man with a wound that was not poisoned. That was why he isolated gangrene cases. What was more, he demanded that the clothes and bed clothes, wards and rooms, and all the requisites of an operation, were kept spotlessly clean. As for the wounds themselves, he proposed to bathe them in a solution of chlorine to destroy the "miasma." Lister, the British surgeon, further developed the tenets of anti-infectious, i. e., antiseptic, treatment.

Strange as it may seem, it was something connected with municipal public works that greatly helped Lister in improving antiseptic practices, and introducing them into general use. Every city has dumping grounds for refuse and garbage. Nowadays the construction of such dumps prevents obnoxious smells. In the past that was not so. Cities had neither sewage, nor dumping wagons. The smell of rotting garbage spread far and wide. City fathers did not know what to do about it until 1864, when the municipal authorities of Carlisle first made use of carbolic acid. They found this solution highly effective. Sprinkled with carbolic acid, the rotting garbage lost its vile odour.

In January 1865 Lister read Pasteur's article, "Research on Decomposition." It described experiments with rotting matter, and spoke of the causes of decomposition. The author proved that decomposition was caused by living organisms so minute that they were invisible to the naked eye and could be seen only with the aid of magnifying devices. They were everywhere, the article said, in the air and in the water, in the food, in meat, and on the lips and hands. The article described them as living ferments. In their absence, Pasteur contended, there would be no decomposition.

The article absorbed Lister's attention. After all, hospital gangrene, which claimed so many lives, was nothing but the decomposition of tissues; it also spread the foul smell of rotting matter. It was therefore quite natural to link up hospital gangrene with Pasteur's invisible living ferments.

Pirogov's *Elements of Field Surgery* appeared at about the same time in three languages and created a lively interest among the surgeons of many countries. So prominent a surgeon as Professor Lister was no doubt acquainted with it, since it became the handbook of almost all army surgeons throughout the world. Lister, it may be presumed, identified Pirogov's "miasma" with Pasteur's living ferments.

Pirogov's remarkable conjecture turned out to be prophetic. If Pirogov and Pasteur were to be taken at their word, all one had to do to prevent gangrene was to protect the wound from "miasma", or living ferments, those agents of decomposition. Lister was confronted by the same problem that so troubled Pirogov: how to destroy the living agents?

Lister remembered what the city fathers of Carlisle had done to eliminate the foul smells of their dumping grounds. Carbolic acid was the thing. If it eliminated foul smells, it arrested decomposition. That was plain. Meanwhile, decomposition could only cease with the destruction of the living ferments. This process of reasoning led Lister to the notion of using carbolic acid to prevent gangrene. In 1867 he suggested irrigating operative wounds with a solution of carbolic acid, and in 1887, of soaking all bandages in it.

THE WAY TO SUCCESS

PIROGOV, PASTEUR, AND LISTER ushered medicine into a new era—the era of antiseptics. Carbolic acid was soon replaced by new, more effective antiseptic solutions—sublimate, iodine, potassium permanganate, rivanol, and others. Antiseptics revolutionized surgery. They gave the surgeon a chance to probe deeper into the wound. The time had come for him to think of operating on internal organs.

The abdominal cavity was operated upon in 1879 with the use of antiseptics for the first time in medical history. Two months later a surgeon sewed together the stomach and small intestine, and made a communicating opening between them. Close on the heels of antiseptics, i. e., the destruction of germs, came asepsis, or a set of precautions against the presence of microbes in the field of operation. The precautions included sterilization of instruments and accessories—bandages, bedclothes and gowns—that came into contact with the wound and the surgeon's hands.

Thanks to antiseptics and asepsis, the surgeon gradually penetrated to almost all the regions of the human body. His knife was able to reach virtually any organ. He no longer dreaded the peril of suppuration.

The heart alone remained as inaccessible as before. No surgeon dared to approach it with his knife. Doctors were convinced it would stop at the slightest touch of the scalpel.

But this state of affairs could not last long. Genuine science could not reconcile itself with it. Even before the era of antiseptics medical thought worked arduously on the problem of heart operations. It was impossible to operate on the heart, but it was possible to study it. Researchers made experiments with rabbits, cats, and dogs. Some hundred and fifty years before the antiseptic era a scientist pushed a sharp piece of metal into a rabbit's heart. The animal lived on for several months; this proved that life was possible even with a foreign body embedded in the heart. And early in the 19th century it was determined that the heart did not fail, or die, and often remained quite unaffected, when pierced by a thin, sharp needle.

Experiment followed experiment. It was something like an artillery bombardment preceding a decisive attack—a surgical attack on the heart. There was the question, for instance, of how to approach the heart. One prominent surgeon successfully operated on several dogs. He opened their chest cavity, removed portions of two or three ribs, which obstructed access to the heart, cut through the pericardium, drew out the heart, inflicted a wound upon it, and then sutured it. At the surgical congress of 1882 four dogs were demonstrated which jumped, barked, and did everything else sound dogs always did. Each had a sutured heart.

The operations on dogs were of utmost importance. It was not the dogs that mattered, but the heart. The physiological laws governing the function of a dog's heart also applied to the hearts of human beings: the experiments performed on dogs opened the way to the human heart.

But it was one thing operating on dogs. It mattered little to science if several dogs died for every one that survived. Experiments on dogs continued. The International Congress of Surgeons in 1896 also had two such dog exhibits—saved by sutures on the heart. But man's heart remained as inaccessible to the surgeon as before.

THE FIRST VENTURE

THE MOST DIFFICULT PART of the operation, even on dogs, was the suturing. The usual kind of suture, highly effective in all other operations, was unsuitable.

In 1886 the medical press published a paper by Filippov, a Russian doctor, which had bearing on this problem. It contained highly important instructions. Furthermore, it drew upon a wealth of experimental data to suggest an adequate method of suturing the heart. Filippov's paper made the prospects of success in heart operations more tangible.

At the International Congress of Surgeons in 1897 general attention was drawn to a modest man seated near the presiding council and watching the proceedings with great curiosity. He was quite obviously at sea in this numerous and festive gathering. People viewed him with undisguised interest, for rumours had already gone abroad about his uncommon case.

Silver-haired Dr. Rehn told the gathering of a patient who was brought to his hospital with practically no signs of life. The man was wounded in the heart, and his life was waning rapidly. A mere matter of seconds separated him from the grave.

Rehn rallied all his surgical experience and decided on an operation. He knew of the experiments with dogs, and of the investigations on rabbits performed by the Russian surgeon, Sabaneyev, and of all the other studies in this field. He knew what current medical literature said on the subject, and of the attempts to operate on the heart, and of the methods of suturing the heart wound.

But that was not all he knew. He also knew of Farine, a surgeon who in March 1896 ventured upon an operation to stop acute heart haemorrhage. Farine sutured the heart wound, i.e., he performed a cardiorrhaphy, but in vain. The patient soon died of complications.

There was a second case that same year. Dr. Kaplene, another surgeon, was summoned to a patient who had been stabbed in the heart with a sharp knife. Death seemed inevitable. There was not a chance in a million that the patient would live. So the surgeon risked an extreme measure. He incised the thorax in the region of the third intercostal space, spotted the beating, purple roundish heart, and the narrow gash in its wall, which spouted blood. He sutured it, but the patient died an hour later.

Rehn was well aware of all that. He had no other choice, however, and risked an operation. The wound was in the right ventricle. The heart twitched in his fingers amidst the squelching blood as he was suturing it. That was on September 9, 1896, a year before the congress. The congress was attended by several hundred of the most prominent surgeons from all ends of the world. And yet there was not a single one among them, outside Rehn, who had ever held a beating human heart in his hand. There was not a single one, outside Rehn again, who could claim that he had ever performed a heart operation which the patient survived by more than a year.

The man who sat modestly apart from the others rose at a sign, and took his place at the speaker's side. He bowed to the gathering in obvious embarrassment, and then fumblingly took off his jacket and shirt.

A long scar and an unusual depression on the left side of the chest came to view where the ribs should be that cover the heart. The depression rose and fell, as though it was pulsating. There were no ribs in that part of his chest. The surgeon had resected them in making his entry into the chest cavity. The heart beat directly under the muscles. The man was Dr. Rehn's patient.

AUSPICIOUS SUCCESSES

September 9, 1896, was the turning point in the history of heart surgery. That day man's heart ceased to be "inoperable."

All the attempts to render effective aid in heart wound cases were at last crowned with success. Throughout the world surgeons learned that the heart could be operated upon with positive results.

In 1903 Surgeon Shakhovsky performed the first successful cardiorrhaphy in Russia. After that the number of cardiorrhaphies in Russia rose from year to year.

But the problem was still far from solved. The failures were just as numerous as the successes. As of old, the heart operation demanded maximum care, extraordinary skill, extensive experience and, this most of all, composure. In an emergency there can be no delay, no time to glance into handbooks, or summon council. Every second counts in the fullest sense of the word, and the price for lost time is the patient's life.

Nor is there room for undue haste. The surgeon must be calm and collected; he must not lose his head. The heart operation must be performed without a hitch. Yet it is new to most surgeons. Even most of the surgeons who had previously operated on the heart, have had no more than one or two to their record. Hero of Socialist Labour and Member of the Academy of Medical Science of the U.S.S.R. Janelidze, has performed only ten cardiorrhaphies in his brilliant medical career, while the total of all his other operations probably exceeds ten thousand. The greatest number of heart operations that ever fell to the lot of a single surgeon in peace-time are the nineteen operations of Dr. Elkin.

In war-time the number of heart wounds is far greater, but even then it is considerably smaller than the number of wounds on other organs. A senior surgeon of the Leningrad Front in the Great Patriotic War, Kolesnikov, recorded only about a hundred heart wound cases at all the military hospitals of the front. This would mean that even an army surgeon had to deal with no more than one or two heart operations.

Nonetheless, the method of cardiorrhaphy became widespread. It was, and still is used in many countries. In the forty-four years from 1897 to 1941 a total of 319 cardiorrhaphies, or an average of seven a year, was performed in Russia.

Cardiorrhaphy, it may be said, has come into surgery to stay. But to this day even experienced surgeons never know how a cardiorrhaphy will end, although today they have an invaluable ally in the X-ray machine.

CONDITIONS OF SUCCESS

HEART OPERATIONS are extremely difficult, and success in them is comparatively rare. Large arteries and veins lead to and from the heart; the principal blood main—the aorta—takes its beginning there, and all the important vessels are crowded together in a space which is no larger than a man's fist.

The heart is in constant motion. Blood spouts from a damaged heart and floods the field of operation, hiding the heart from sight. The slightest inadvertent movement of the surgeon's knife may cause disaster.

The same Rehn, who performed the first successful cardiorrhaphy, had a few anxious minutes in his second operation. He describes them as "minutes that are hard to forget."

Rehn had opened up the patient's heart, but failed to spot the wound.

Meanwhile, the blood was inexorably flooding the field of the operation. Rehn groped blindly for the wound with his fingers, and, finding it, pressed his finger down upon it. But that did not stop the bleeding. He sutured it. The blood spouted on. His assistant also pressed his finger upon the wound, and also to no avail. The patient died.

The pleura, the lungs, and the diaphragm, are all in close proximity to the heart. They are also liable to be damaged in a heart operation if the entire site of the operation is not open to the surgeon's view.

That is what makes cardiorrhaphy so difficult. Only high operative technique can ensure against blunders, and failure. That means improved methods of opening the chest, determining what portion of the rib or ribs should be resected, pulling out and holding the heart, draining the accumulated blood, and deciding how deep to make the suture. Technique is of utmost importance in cardiorrhaphy. Today several methods of the operation have been worked out, which are accepted by almost all surgeons.

An opening is cut in the chest in the region of the heart with three strokes, and the resultant flap, consisting of skin, muscle, and bits of ribs, is turned back; the heart is then open to the surgeon's view. All he has to do is to find the wound. If the wound is not readily located, the heart may be slightly drawn out, but this must be done with extreme care. Then it will lend itself to a detailed examination. The next step is to suture it, after which the bleeding stops. The lost blood is then removed and the skin flap replaced in its proper position. That is one of the better methods, known as the flap method.

There is yet another technique. First a cut is made in the space between the third and fourth, or the fourth and fifth, ribs. Usually it is the space where the blow was delivered. If the heart wound is not detected, the cut in the chest is widened. In widening the cut downwards a portion of the fourth or fifth rib is resected. The same is done with a portion of the fourth or third rib in widening the cut upwards.

Sometimes the surgeon has to resect part of the fifth rib as well as parts of the third and fourth. But all this is done step by step. Having disposed of one rib the surgeon tries to spot the wound in the heart without going further. If he fails, he tackles the next rib. This method is known as the method of progressive widening.

There are other methods. But whatever their number and name, they all have a common goal: to bare the heart as quickly as possible, locate and suture the wound. What method to choose, is the surgeon's affair. A method suitable in one case, may be useless in another. It depends upon the location and type of wound, the quantity of blood lost, the state of the neighbouring organs, the time when the wound was inflicted, and upon many other circumstances.

A heart operation is always an emergency operation. For that reason it is highly important for the surgeon to know of definite indications that would help him in choosing the most suitable method.

Janelidze, of whom we have already spoken, has worked out such indications on the strength of his own extensive experience and the experience of other surgeons.

In doubtless heart injuries Janelidze proposes the flap method, which opens broad access to the heart and saves valuable seconds in the search for the wound. But if a heart injury is doubtful, and the wound may have been inflicted on some other neighbouring organ, the method of progressive widening is preferable.

That is all. At first glance it is next to nothing. But in choosing the method of cardiorrhaphy these indications are invaluable. They are simple, and it is this simplicity that is their principal merit. Time is an all-important and decisive factor in cardiorrhaphy, and the indications of the Soviet scientist save numerous human lives.

Operations rarely pass without a hitch. Unforeseen contingencies creep up upon the surgeon in almost every operation. It is either the bleeding that will not stop, or the knife that inadvertently penetrates the pleura or the lungs, or the respiration that ceases, or the heart that suddenly fails.

The surgeon must instantly apply artificial respiration, massage the heart and—this under all circumstances—make a blood transfusion. All doubts about the latter have been cleared up: it is a reliable and effective factor in all heart wound cases. But even before transfusion became generally recognized, the results were highly illustrative. In the five years between 1901 and 1905 the number of heart wound patients who survived constituted 30.5 per cent. In the five years between 1911 and 1915 this figure rose to 56.5 per cent. Mortality in the second five-year period dropped almost by one half.

That was a big advance.

A WAY OUT

THE INCREASING EFFECTIVENESS of heart operations is explained by the brilliant development of science and, particularly, of the technique of cardiorrhaphy.

Russian surgeons made a noteworthy contribution to it. The number of cardiorrhaphies in Russia represented almost one half of all the cardiorrhaphies in the world. The research of Russian scientists played a leading role in perfecting the methods of cardiorrhaphy.

What is most important in a cardiorrhaphy? Is it obtaining access to the heart? Or exposing it? Or finding the wound, which is often extremely difficult? No, the most important thing is to suture the wound.

The heart muscle never rests. It contracts and relaxes alternately, and its contractions are fairly vigorous. The sutures often tear the muscles, the wound re-opens, the bleeding begins anew, and death comes dangerously near. Surgeons had to learn to suture wounds without jeopardizing the heart muscle. The latter had to be re-inforced. Only then could they expect to achieve real progress in the technique of cardiorrhaphy.

In 1898 a prominent surgeon sewed together the heart wound and the adjoining region of the pericardium. Certain other doctors followed his example. At first this seemed to be a happy solution, for the pericardium is close at hand, and, what is more, its tissue is by no means foreign to the heart muscle. But soon came disappointment. The measure often failed to prevent a lethal outcome. Another method was tried. In 1912 at a surgical congress a report spoke of a patient operated for a heart wound. The suture cut the heart muscle. The blood spouted out of the wound, and the patient was on the brink of death. The surgeon decided to cut off a bit of the chest muscle and close up the wound with it. The stitches passed through both the chest and heart muscles, and held firm. The bleeding stopped at once. Yet the patient died five days later. The same sad result was observed by other surgeons who transplanted muscle to the heart. The bleeding ceased. But the transplanted bits of muscle died, and caused pericarditis, an inflammation of the pericardium which was a dangerous complication for a wounded heart. Furthermore, the dead bit of muscle became a breeding ground for pathogenic microbes.

Muscle transplantation was given up.

The problem, it appeared, had come to a dead end. It was the privilege of Russian surgeons to solve it. Firstly, Janelidze turned his attention to the fascia—the fibrous tissue that covers the muscles. It is continuous with other connective tissue, such as the tendons, which bind the muscles to bone. The fascia, he found, suitably reinforced the wounded heart muscle. Janelidze cut a strip of fascia from the muscle known as pectoralis major, which is near by, laid it on top of the wound, and sutured it together with the heart muscle, much as a tailor does, who puts a patch on flimsy cloth. Fascia, strong and yet thin, serves its purpose splendidly. The sutures do not cut the heart muscle. The bleeding stops almost without fail. As for infections, the fascia is a poor medium for microbes and suppurations.

That probably explains—with all due respect for the surgeon's skill—why the four cardiorrhaphies made by Janelidze in 1911, 1912, and 1913, all ended successfully.

Secondly, in cases where fascia was unsuitable, it could be replaced by fat. A bit of fat sutured to the wound was also highly effective: the bleeding stopped and the sutures caused the muscle no harm. Connective tissue eventually developed in place of the fat. The ease of obtaining the fat, and its property of "sticking" to the wound, helped to solve the problem.

Nedokhlebov, a Russian surgeon, was the first to apply fat in a cardiorrhaphy in 1914. He knew of Dr. Portyagin's paper, which described cells of fat as blood-stopping agents. He also knew of the successful experiments made by Polenov and Lodygin in 1913, who transplanted fat in cases of liver, spleen, and kidney haemorrhage.

The use of fat in suturing heart wounds yielded beneficial results. Dr. Pikin, and other surgeons, followed Nedokhlebov's example. Gradually the new method was also adopted abroad. The use of fat and, in certain cases, of fascia, increased the number of post-operative recoveries.

THE HARVEST

IN THE PRE-ANTISEPTIC ERA heart wound patients were never operated. But they did not all die. As we have said, forty-two of four hundred, or ten per cent, survived.

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That means recovery is possible without surgical intervention.

In 1941 stock was taken of all the heart cases operated since 1896. They totalled 1,000. Of these 498, or almost 50 per cent, recovered. Surgical treatment was therefore five times as effective as the wait-and-see method. Clearly, an operation is indispensable in treating heart wounds. Every heart wound patient must be operated, however hopeless his condition may be.

Surgeon Yushkova handled an absolutely astounding case. She performed an operation that has few to equal it in the history of cardiorrhaphy.

While examining a revolver a nineteen-year-old girl inadvertently pressed the trigger. The bullet passed through her heart. Certain symptoms helped to determine that it penetrated the abdominal cavity. Two hours later the girl was put on the operating table.

Yushkova made her first incision. She found the left ventricle pierced, and sutured it. But a gurgling sound in the thorax every time the patient inhaled showed that the pleura was also perforated, and Yushkova sutured it too. The abdominal cavity was opened up next, to extract the bullet. The surgeon found a hole in the diaphragm, and sutured it, as well. Then she discovered that the liver was damaged, and sewed it up, and also sewed up the large intestine below the liver, which was also punctured. Finally, Yushkova located and extracted the bullet.

Although the patient's condition had appeared hopeless from the first, Yushkova stubbornly repaired damage after damage. She did not give death the benefit of even the slightest chance.

A month after the operation the young woman was discharged from hospital.

This shows that if there is cause to operate, the operation must be performed under all circumstances. The surgeon must not hesitate even when the patient's condition leaves no room for hope; even when the pulse is absent, even when agony has set in. While there is still a spark of life in a patient everything must be tried to save him. That is exactly what surgeons do. And that explains the 50 per cent of survivals.

But it is not only a matter of percentages. The wounded returned to normal.

True, it is not always possible to find out what subsequently happens to the patients. It is not easy to locate a patient five or ten years after an operation and ask him how he is. But information is available about quite a few of them.

A shoemaker operated by Janelidze returned to his trade and lived as he had lived before he was wounded.

Surgeon Magula's patient was a carter. Ten years after his operation he hauled loads just as he had done before it.

Some of the patients were even called up for military service.

A stevedore who had had a cardiorrhaphy complained about a heaviness in the region of the heart whenever he picked up a load weighing more than a hundredweight.

After a cardiorrhaphy one of Janelidze's patients contracted syphilis. Then he had scurvy, and then typhus and relapsing fever, pneumonia and pleurisy. Finally, he had a bad case of influenza. All this in twelve years. Yet his sutured heart bore it all.

In 1916 Professor Grekov performed a heart operation. Six years later his patient came for a medical check. In the absence of the professor another surgeon examined him. The patient was found to be fit. He had a normal pulse, and normal heart tones. He could easily walk 30 miles and climb to the sixth floor several times a day. Only the scar on the left side of his chest, which receded a bit every time his heart contracted, reminded of his heart operation.

The results are not always so good. But often enough they are. Compared to the past, even the recent past, great headway has been made.

The extraordinary skill of the surgeons of our day holds out good prospects of new successes in heart surgery. In the Soviet Union the achievements of cardiorrhaphy are very great. Before the October Revolution 73 of the 109 operations performed in Russia fell to Petersburg. Only four cardiorrhaphies were performed in Moscow. Anyone wounded in the heart somewhere in Irkutsk, Voronezh or Tashkent could not expect surgical assistance on the spot. In the U.S.S.R., cardiorrhaphies are feasible in such towns as Chardjou, for instance, or Chimkent and Yakutsk—places that were out-of-the-way holes before the revolution.

The heart, inaccessible for many centuries, was, at long last, "taken." It has become a full-fledged "surgical" organ.

TEMPERATURE TAKES A HAND

NEW METHODS OF ANAESTHESIA hold great prospects in the sphere of heart surgery. Modern methods are not confined to switching off the consciousness, or eliminating pain reactions in operations. A method suggested in recent years, which reduces the pathological reaction of the body to the process of the operation itself is being put to practical use. It offers the opportunity of adjusting metabolic processes, respiration and blood circulation. This method is based on hypothermia.

Hypothermia is the Greek for abnormally low temperature. It stands to reason that this refers to an abnormally low temperature of the human body.

The normal body temperature is 98°—98.5°F. Anything above that is symptomatic of sickness. The implications of high temperatures have been thoroughly studied for each particular disease.

But what happens if the body temperature drops to 90 or 88, or even 85 degrees?

That was a question that has long interested doctors. And in recent years the number of researchers dealing with it, has become particularly great.

Curious phenomena came to light. Firstly, researchers determined that general cooling of the body under anaesthesia slows down metabolic processes, lowering the body's oxygen requirement and raising the resistance of the cells of the central nervous system to an oxygen deficiency. Respiration is sluggish and superficial, the pulse decelerates, and the blood stream slows down, reducing the danger of blood loss. The body retains its viability, but it requires much less nutrition and minimum supplies of oxygen.

Of course, it is unable to sustain itself for any lengthy period under such circumstances. There is a certain time limit, after which all life, however weak, terminates for good. But within this time limit the body may be returned to normal, its functions restored in full.

Slower process in the cells, tissues and organs, and the possibility, under certain circumstances, of restoring them to their normal state—all this has been scientifically substantiated.

It goes without saying that the body can stand cooling only up to a certain point. For human beings this point is 82°F and 72°—68°F for animals. Cooling below this temperature is fatal. The centres of respiration and the cardio-vascular functions will not return to life in that event. Irreversible changes—disintegration and destruction—take place in the cells.

But what have heart operations to do with hypothermia?

Serious operations, such as operations on the heart, tax the endurance of an organism not only during the operation, but after it. Meanwhile, experiments performed on animals, and observations made of human beings, show that a body cooled to a low temperature acquires greater endurance for a considerable period. Experiments with animals also show that the heart of the cooled body of an animal is capable of returning to life and performing its normal function even after a stoppage of twenty minutes.

It stands to reason, the procedure of stopping heart activity is far from simple. The heart contracts only when it is supplied with blood. A part of the blood nourishes the heart muscle, reaching it by the coronary arteries. If its access to the heart is obstructed, such nutrition stops.

Blood is conveyed to the heart by the lower and upper venae cavae. Hence, if the circulation is obstructed in these two veins, the blood supply to the heart will cease, and so will the nourishment and function of the heart muscle.

But how to stop the flow of blood in the venae cavae? Use is made of soft clamps. The two veins are compressed with soft clamps near the junction with the heart. Clamped in this manner they no longer pour blood into the heart. The heart does not fill with blood. It becomes what surgeons call "dry."

It is easier to operate on a "dry" heart. Blood gushing from a beating heart and flooding the operation field creates great difficulties to surgeons. The heart often tears the sutures. All this makes the surgeon's work hazardous, and prevents him from thoroughly examining the wound, all of which has an adverse effect on the post-operative condition of the patient.

The twenty minutes in which the animal's heart is still make possible a thorough examination of all its parts, and provide for utmost certainty and precision in all the necessary surgical operations.

The clamps on the veins are then removed and the heart is returned to its function. It begins to contract, and restores the circulation of blood in all parts of the body.

But we know that if the heart stops, the nourishment of the brain cells, including the vulnerable cells of the higher cerebral centres, is arrested. We also know that if nourishment of the brain cells ceases for more than five minutes, these cells, which govern the most important organs, including the heart, undergo irreversible, fatal changes, and perish. The heart cannot beat again if the brain cells that govern it, are destroyed. It would appear, then, that a period of twenty minutes is all the more disastrous.

But all this is true only under normal conditions. Hypothermia extends the period of reversibility in animals to 18—20 minutes and in men to a somewhat shorter period. It makes a break in the supply of nourishment to the brain for a certain period quite harmless. It is an invaluable aid in extensive operations on the thorax. It allows surgeons to make close examinations of the heart, and to inspect its valves and cavities. It expedites operations on the cardiac valves, enables surgeons to remedy defects in the heart partitions and to widen strictures in the heart valves. Operations that only yesterday were dismissed as mere figments of the imagination have become feasible with the help of hypothermia.

One more question. How can the body temperature be lowered artificially to 86^0—82^0F at the doctor's will?

There are compounds, which lower the temperature. They are usually applied in combination with a physical agent—cold water. The patient is wrapped in a blanket with twin rubber walls. Cold water approaching 37^0—41^0F is circulated within the blanket. The body, wrapped in such a blanket before the operation, cools to the desired temperature gradually. A suit with similar twin rubber walls may substitute the blanket.

After the operation the same blanket is used to return the body to its normal temperature: the cold water in it is replaced by hot water.

Considerable experience has already been accumulated both abroad and in the Soviet Union in the application of hypothermia in surgical operations. It holds good prospects for the development of surgery, and particularly surgery of congenital heart diseases. However, many aspects of this intricate problem still have to be defined, studied, and theoretically substantiated. It is also necessary to study the delayed results of temporary artificial body cooling.

The Seventh Scientific Session of the A. V. Vishnevsky Surgical Institute in November 1955, devoted to hypothermia, was an important milestone in the development of that method. The session summed up the results of experimental research and practical application of hypothermia in Soviet clinics, making note of both its successes and failings. The session plotted paths of further research in that new medical sphere.

ONE MORE STEP

THE PROGRESS OF SURGERY made it possible to operate on the heart, suture its wound, and stop haemorrhage. In the main, surgery confined itself to such interventions, and went no further. Unquestionably, that was a great deal and represented a tremendous advance. But often it was insufficient. Fragments of shells, or bullets, often lodge themselves in the heart itself. That naturally complicates the picture. The surgeon must stop the bleeding and suture the wound. He must also locate the foreign object and extract it. The latter proceeding is not at all easy. Sometimes it is quite impossible. The surgeon must often cut the wall muscle of the heart, inflicting an additional wound. This alone is enough to make the operation unutterably grave.

It is hardly surprising that even the boldest and most experienced surgeons were reluctant to perform that kind of an operation. While ordinary heart suturing was not quite a novelty any longer in various countries, the discovery of foreign objects in the heart made the case inoperable.

In exceptional cases the patient might survive with a fragment or bullet lodged in the heart. But surgeons were convinced that any attempt to extract them, i. e., to cut the heart muscle, meant certain death.

This point of view, which reigned for many years, was dispelled in 1905 by a Russian surgeon of Yuriyev University. A young woman was brought in with a chest wound. She was hit from a pistol twenty minutes before, and her condition was serious. The surgeon found a tiny hole in her chest, but no second hole to show that the bullet had left the body. There were unmistakable signs that it had lodged itself in the heart or near it. The uncertainty of its exact location had the greatest bearing on what came after. The chance of saving the woman, as medicine would have it in that day, hinged on the hope that the bullet was embedded somewhere outside the heart.

The operation began. The surgeon exposed the heart. The wound was in its front wall, in the region of the right ventricle. The surgeon sutured it, and in making the final stitch his fingers encountered a solid object in the heart muscle. The bullet had penetrated the front wall, passed through the cavity of the ventricle, and lodged itself in the back wall of the heart.

That was just what the surgeon had feared most. To reach and extract the bullet he would now have to incise the wall of the ventricle. But that would mean a second wound to a heart muscle already damaged and copiously flooding the site of the operation with blood. Moreover, the surgeon would have to manipulate on the back wall of the ventricle, which was hidden from view. In that day it all appeared virtually impossible. To top it all, the bullet was lodged in the immediate neighbourhood of the descending branch of the right coronary artery. Utmost care was required to avoid damage to this vital vessel.

The life of the patient hung on a thread, as it were, which grew slimmer and slimmer with every passing second. But the surgeon hesitated only for an instant. The operation continued. He drew out the heart as far as it would go, transfixed the heart muscle with two sutures, and cut the back ventricle wall. The cut was made in the direction of the bullet, opening access to it.

The silence of the operating room was soon broken by the sound of metal striking glass. The doctor had extracted the bullet and dropped it into a bowl. The operation ended happily.

That was how Manteufel, a Russian surgeon, made medical history in Yuriyev on September 12, 1905.

But the success of the operation had almost turned into dismal failure. The bullet had almost slipped into the cavity of the heart ventricle through the wound opening. That would have added to the difficulty of an operation that was already extremely complex. To grope for the bullet in the heart cavity while spurts of blood flowed in and out of it and the cardiac valves were in full operation, would have been a hopeless task. Not a single doctor of that day would ever have thought such a thing possible.

Only much later it developed that the art of surgery could achieve success even in such circumstances. Medical texts describe cases, in which foreign bodies were removed from the cavities of both ventricle and auricle. Operations of this kind took their legitimate place in surgery.

AMENDMENT TO OPERATIONS

In the Second World War, which involved millions of men, cases of shell fragments and bullets lodging themselves in the heart, were comparatively frequent. More than a hundred such cases were treated at the special hospitals of the Leningrad Front alone.

Soviet doctors discovered a highly curious thing. In certain heart wound cases, with a fragment lodged firmly in the heart wall, or even inside the heart cavities, the general condition of the patients gave no cause for alarm. The victims lived for months without suffering any discomfort. They could perform various work, and help their ward mates in spite of orders to the contrary—and all without any visible harm. The heart, though wounded, possessed far greater endurance than surgeons previously supposed. Some people lived for years with shell fragments and bullets in their hearts, without visible complications.

All that the heart can endure is best illustrated by the story of a certain machine-gunner. The fragment of an enemy mine pierced his chest. It damaged the pleura—the tissue that covers the lungs. This gave rise to pleurisy, a fairly serious complaint, particularly dangerous in the patient's weak condition. Yet when the machine-gunner was brought to a special hospital a fortnight later, his condition was satisfactory. Only the heart tones were slightly muffled, but that gave no cause for anxiety. He had had a transfixing wound, and there seemed to be no question of a fragment in the heart. Nobody ever thought of looking for any fragment. And the patient made no complaints.

But he suffered from occasional pains in the region of the heart, and the doctors made an X-ray. To their surprise a metal fragment was discovered in the heart wall.

The puzzle was quickly solved. The metal object was a bullet which had lodged itself in the heart long before the soldier received the mine wound. The bullet had penetrated into the heart more than 12 months before, and yet he had no inkling of it. It was lodged in a place where it could not easily be discovered by ordinary physical examination. Furthermore, it never bothered the patient. He had been dehospitalized that time and sent back to his army unit, where he bore the hardships of firing-line life without any visible adverse effects.

Doctors watched the unusual patient for two and a half months. Since the pains in the heart persisted, they decided to extract the foreign body. But the bullet had penetrated into the thick of the heart muscle. It would be a risky job to touch it and brave excessive blood losses. There were many rough adhesions and changes in the heart muscle, which made the operation difficult. There was reason to fear a lethal outcome, and the operation was terminated. The bullet was left where it was, and the incisions were sutured.

The machine-gunner got well. He left the hospital in a satisfactory condition. The information about himself, which he sent his doctors from time to time, said that he was well.

Surgeons arrived at an amazing conclusion: it was sometimes more advisable to avoid an operation. In such cases the old maxim holds true that a surgeon's duty encompasses not only skilful operations, but the healing of patients without an operation if possible.

With heart surgery what it is today, an operation, whenever desirable, is performed expertly and quickly. The continuing improvement in technique, and new remarkable antiseptics such as penicillin, enhance the chances of full recovery. But it is the greatest merit of modern surgery that doctors know when an operation is urgent and unavoidable, and when it may be postponed, or avoided altogether. Soviet surgeons have accumulated vast experience in that particular field. Their research is an invaluable contribution to world medicine. At wartime Leningrad Front hospitals only forty of the hundred patients with foreign bodies in their heart, or near it, were operated. The other sixty lived on with bits of metal in the heart muscle or pericardium. They were not operated upon in view of possible complications.

Yet there are cases in which the bullet must be extracted even when lodged outside the heart, and the patient is feeling fit. There may be no apparent reason for an operation, but whenever a bullet or shell fragment lodges itself in the immediate proximity of the major vessels, for instance, at the mouth of the aorta or the venae cavae, it must be removed without delay. A sharp turn, a chance movement, or some strain may cause the bit of metal to dislodge itself. It may puncture the wall of a blood vessel, causing internal haemorrhage—an extremely dangerous condition which puts the life of the patient in the balance. Experience shows that in such cases it is inadvisable to postpone an operation for any length of time.

But that does not change the basic proposition. Not all heart wounds require an operation. To conquer the heart surgically does not always mean operating on it. It often means the contrary. Present-day surgery, as we see, has made its amendments to the indications for cardiorrhaphy.

RADICAL TREATMENT

THERE IS A COMPLAINT KNOWN as angina pectoris. If neglected, the disease has grave developments and often ends in the death of the patient.

The ailment is due to stricture of the coronary arteries, which feed the heart muscle. It occurs mostly in people who have arteriosclerosis and atherosclerosis, when sediments are precipitated on the walls of the vessels, hardening them and obstructing the normal flow of blood. The heart, active night and day, requires an unintermittent and abundant supply of nutrition. In sclerosis of the coronary arteries too little blood is brought to the heart muscle and the latter suffers a shortage of nutrition. The heart is then over-taxed, and pathological changes occur in it, causing angina pectoris.

There are several treatments for angina pectoris, depending on the extent of changes both in the blood vessels and the heart muscle. But when the disease is far gone conservative treatment brings only temporary relief.

Meanwhile, it is only a matter of increasing the supply of nutritive substances to the heart, of raising the blood supply to its muscle.

Angina pectoris is usually treated by physicians, i. e., specialists in internal diseases. Yet, at least for the present, they know no treatment that would completely restore the blood circulation in the heart. The question of radical treatment must consequently be viewed in the surgical plane.

Modern surgery has two powerful weapons—blood transfusion and penicillin. Surgeons today have nothing to fear from even the acutest haemorrhage, or infection. They can open up the thorax, incise the pericardium, draw out the heart, and connect it with a strip of tissue from the blood vessels that feed it. The heart must then be replaced in its former position, the pericardium sutured, and the thorax closed up.

The blood vessels of the strip of attached tissue take root, so to speak, in the heart muscle, and take a hand in supplying the heart with blood. The strip of tissue must naturally be taken from somewhere very near the heart—the sternalis, a muscle parallel to the sternum, or the sebacious muscle, which is pulled up to the heart from the abdominal cavity through openings made in the diaphragm and pleura.

A soldier was wounded in the chest in 1944. The fragment lodged itself in the heart muscle. Adhesions developed soon after between the pericardium and the heart, deranging heart activity. Blood circulation in the heart wall deteriorated. The man was in a bad way. He was weak, and bent low as he walked. An electro-cardiographic investigation showed that the supply of nutrition to the heart muscle was disastrously low.

In January 1947 Professor Kolesnikov of the Kirov Medical Academy, operated on him. He extracted the fragment, although it was buried in a mass of scars and adhesions. But that was not all. He also removed a bit of the pericardium, which had hardened due to the scars, and substituted a strip from the sebacious muscle.

Two months later the patient's condition took a marked turn for the better. The heart pains disappeared. He no longer experienced any difficulties in breathing. The recent invalid took a job with a department store, where he had to be on the move all day long. A post-operative electro-cardiographic investigation showed that the heart muscle was receiving an adequate supply of blood and nutrition. The blood vessels of the graft had obviously taken root, and fed the heart muscle.

Professor Kolesnikov described the case at a sitting of the Leningrad Pirogov Surgical Society on March 12, 1947.

Armour heart is another rare and serious complaint. It is not a disease of the heart itself, to be exact, but of the pericardium. The pericardium envelops the heart like a soft sac. In some cases the sac tends to grow hard. As a rule this is caused by prolonged pericarditis, a chronic inflamed condition of the pericardium. In pericarditis the soft sac turns into a hard, unyielding envelope which covers the heart like armour plate. As the pericardium hardens, the heart beats more weakly. Blood circulation slows down. The blood stagnates in various regions of the body, giving rise to an extremely serious disorder of the vital processes. With time the disease becomes fatal. But that was in the relatively recent past. Medical progress has turned the tables on armour heart.

In the summer of 1948 a patient was brought to one of the Leningrad clinics. It was a girl of nineteen. She was in bed most of the time, for even a step or two caused a sensation of suffocation. Her pulse was almost imperceptible. She had oedema from top to toe, and her abdomen resembled a large watery pillow. Fluid had gathered in it from the stagnant vessels of the abdominal cavity. The veins stood out on her neck like thick ropes, overfilled with blood due to the sluggish activity of her heart. The kidneys functioned poorly, and the liver was dilated. Life hung on a thread in this long-suffering body, and all because of the "armour" that held the girl's heart in a grip of iron.

She had spent months at a clinic of internal diseases. But there had been no improvement. The physicians were helpless in her case. There remained just one alternative—one that would never have entered anyone's head some ten years ago. It was surgical treatment.

At the surgical clinic an operation was made. Under local novocain anaesthesia the patient had her thorax opened by the flap method: parts of several ribs and a portion of the sternum were removed, affording easy access to the heart. The surgeons saw a hardened pericardium, which held the weakly beating heart in its vice-like grip. The grip had to be loosened. It was a risky undertaking, however, because the pericardium might have formed adhesions with the heart muscle, and the surgeon would then have to cut it off, wounding the heart.

The surgeon, a man of great experience, bold and yet cautious, cool and yet inwardly tense, made the first incision. Short strokes of the knife enlarged the opening in the hardened pericardium. When he finally reached the heart, he had to peel off the pericardial tissue.

The heart would then be free to beat normally. The deadly armour would be cast off.

Suddenly a complication arose: the blood pressure dropped dangerously. The heart was coming to a gradual stop. The moment was fraught with peril. It could end in death. But modern methods were brought into play instantly.

The operation was stopped. The wound was covered with large sterilized napkins. One of the surgeon's assistants, who had watched the pulse and blood pressure, pushed a needle into the girl's vein. A rubber tube led from it to an ampoule of blood. Almost a quart of blood was transfused. Thirty minutes later the operation was resumed.

Late in 1948 a young woman came to the Leningrad Pirogov Surgical Society. She climbed the stairs easily to the second floor, walked with a springy step down the corridor, and entered the study of the chairman of the Society. Hero of Socialist Labour, Professor Janelidze, told a gathering in the chairman's study how he operated on her armour heart. The young woman, in the full bloom of her youth, stood beside him. A curved scar on the left side of her chest was all that remained of the deadly "armour" that had sheathed her heart.

At the time Professors Kolesnikov and Janelidze made their reports to the Pirogov Society such operations as they had performed were extremely rare. Since then heart surgery has made important headway. Today operations for angina pectoris and other heart diseases are recorded by the hundred. In 1955 Professor Kazansky, of Moscow, reported ten such operations. All his patients had been in a bad way. The operations returned them to health. The story of Chuiko, a 60-year-old railwayman, was particularly interesting.

His case had seemed hopeless. There was general atherosclerosis and scars had formed on the heart muscle after an infarct, i. e., haemorrhage of the heart wall. He had spent months in bed and suffered from continuous heart pains. Drugs did not help.

Three weeks after Professor Kazansky operated on his heart. Chuiko walked unfatigued for hours about the hospital garden and easily climbed the stairs to his third-story ward. He forgot, as he put it, where his heart was, while less than a month before he could hardly make a score of steps on even ground. In another three months Chuiko returned to his work.

In some cases, as we see, heart diseases are passing out of the sphere of therapeutics into the sphere of surgery.

A SECOND HEART

IN RECENT YEARS MEDICAL TEXTS have been reporting an advance upon the heart from yet another, somewhat unexpected, quarter.

There was a frog at Professor Sinitsyn's laboratory in Gorky which attracted the attention of all physiologists. It looked like any other frog. It ate, slept, woke up, and croaked like the others. But for all that it was an uncommon specimen, for it did not have the heart it was born with. Some other frog's heart beat in its breast. Professor Sinitsyn's experiment was remarkable in two ways. Firstly, he excised the frog's own heart and replaced it with another frog's. Secondly, he did not damage any surface tissue in doing it. The removal and transplantation were both effected through the frog's mouth.

It was a miracle of experimental surgery. The new heart substituted the old in all respects. For twenty months—a long term for a frog's brief lifetime—the transplanted organ did its duty splendidly.

The frog, however, is a cold-blooded animal. That makes comparisons difficult. There is a world of difference, physiologically speaking, between cold-blooded and warm-blooded animals. Sinitsyn's experiment is in itself highly remarkable, but it gives insufficient reason to expect similar results in higher animal species. That sort of analogy could be drawn only from experiments on mammals. The higher the animal stands on the ladder of evolutionary development, the more complex and delicate its organism, and the less readily it submits to artificial change. Yet Professor Sinitsyn, and after him the physiologist Demikhov, solved even this fascinating but almost insolvable problem. They did what no one, anywhere, ever did before them. They transplanted the heart of a dog.

The dog had two hearts. One of them was its own. The other was transplanted into it from the fresh corpse of another dog. And both hearts beat.

The experiment was repeated on dozens of dogs. And it succeeded in each case, proving that the first attempt had not been a mere fluke.

The technique of grafting was extraordinarily difficult. The blood vessels of the second heart had to be attached to the major blood vessels in the thorax. This connected them to the body's circulatory system. Demikhov improved upon Sinitsyn's method in some of his experiments by transplanting the lung, and often even both lungs, along with the heart. As a result, the transplanted heart was equipped with its own vessels, and even part of the lesser, or pulmonary circulation.

It may puzzle the reader why the researchers did not remove the dog's original heart after implanting a new one. But that is easily explained. If the circulation of the blood in the dog's body ceased for anything longer than five or six minutes the animal would die. The interim between the extraction of the original heart and the moment the new heart began to function, would necessarily have been longer. The old heart would cease its work before the new one would take up its duties. The animal would be dead by then.

It stands to reason that the operation, attended as it was by such radical changes in the cardio-vascular system, did not pass off without a hitch. In fact, the dogs suffered from occasional lapses in the heart activity.

In one of the dogs the complications were particularly acute. Its pulse grew suddenly weak, and its blood pressure dropped. It was on the brink of death, but just as suddenly the pulse improved some five minutes later, and the dog gradually returned to normal.

It turned out that the dog's original heart, which had done the lion's share of the work up to that moment, had stopped beating. The transplanted heart, which had been beating almost imperceptibly until then, suddenly filled with blood, and took over its function, pumping blood through the entire body. The second heart supplanted the first.

The organism of man and animal possesses an amazing capacity for vicarious function—one organ taking over the function of its diseased fellow. One of the kidneys may be failing in a human body, for instance, due to stones, or as a result of a tuberculous process. It is then surgically removed, and the second kidney takes over its function, and even increases in volume to cope with the new task.

If a large artery were clamped, minor arteries, even capillaries, would assume its duties. They would grow in size until able to cope with the entire blood stream. Failing this, the tissues would be deprived of nutrition, and would die. All this is a physiological law.

Sinitsyn and Demikhov showed to what extent science can impose its will upon nature. The dogs with two hearts lived eight to ten days. They died after that, but it was not from the transplantation itself, but from pleural complications, infections, and the disintegration of neighbouring tissue—all of which point to the extreme difficulty of transplanting so delicate a mechanism as the heart.

The technique of grafting will unquestionably improve. Complications will be avoided. The new heart will perform its functions as well as the original one. There will be no need to preserve the old, already worn-out organ. It will be excised.

The dogs will not die then. On the contrary, their life, sustained by a fresh heart, will be prolonged.

Yet all these experiments are not meant solely to prolong the life of dogs. Their purpose, in the final analysis, is to lengthen human life. It is too early as yet to speak of that with any degree of certainty. But all in all it is plain that science is opening new, unusual, even if distant horizons.

The speedy, convenient and simple method of joining blood vessels by means of a special apparatus designed by Soviet scientists, which we have already mentioned, will no doubt play a decisive part in advancing the issue. The replacement of a diseased heart with a sound one, as soon as that will become possible, will go down as a major triumph in the history of medicine.

CHAPTER SIX

TO TAME TIME

UNCEASING QUEST

TOWARDS THE CLOSE of the fourth century Alaric, king of the Visigoths, devastated Thrace, Macedonia, Thessaly and Greece. In A.D. 410 he marched on Italy and sacked Rome. He captured fabulous riches, and his power over men was limitless.

But Alaric grew moody and taciturn. Thoughts of old age and approaching death pursued him. He announced far and wide that he would give all his wealth and power to anyone who would lengthen his life and return him his former strength.

Messengers rode through his far-flung possessions in search of a man with the magic gift of restoring youth. They found a soothsayer, who claimed the secret of eternal youth. He was brought before Alaric with pomp and honours.

The king of the Visigoths saw a shrivelled, wasted old man, who shuffled his decrepit legs with great difficulty.

"How old are you?" the king asked.

The soothsayer said he was 68.

"I should have died at twenty," he explained, "but thanks to my magic drink I've lived to this day and expect to live another five years."

The infuriated Alaric, who was then 74, had him decapitated.

This legend mirrors mankind's oldest dream—the dream of longevity, the dream which at all times haunted people in old age. The alchemists of the Middle Ages, cloistered amidst retorts and beakers, and stills of the strangest shapes and forms, within walls covered with cabalistic designs and mysterious formulas, sought for the "philosopher's stone," which would obtain them gold from common metals, and eternal youth.

Generations of alchemists came and went, but the problem of lengthening life continued to occupy men's minds. People work on it in our day.

HOW LONG MAN SHOULD LIVE

MAN GROWS OLD AND DIES. Such is the law of nature. It applies to all organisms. Certain cells of the human body die several times over in a man's lifetime, and new ones appear in their stead. It has been established, for instance, that 300 to 400 billion red blood corpuscles disintegrate in man's blood daily, and just as many new ones are born. Each second 125,000,000 cells die in our body, and are replaced with new ones.

When the skin peels, billions of epithelial cells die and are replaced by new ones. Kidney cells are renewed, and so are the cells of the liver and the intestines. In some organs this process is rapid, in others it is slow.

But not all cells are renewed. The brain cells, for instance, are not. Their number may be reduced through the destructive action of various diseases, but it can never increase.

It is not as simple as it may appear to determine how long a man should live. Some people die at thirty, others at forty and fifty, and others still at seventy and eighty. Some live to be a hundred and more, and others die when still young. All in all, most people die under one year of age.

All these figures lend themselves to a calculation of the average human life span, but that by no means tells us how long man could really live under favourable conditions.

Old age is generally fixed at three score and ten. The average life span, however, is much shorter, approximately fifty years. That is easily explained. In calculating average life expectancy statisticians account for both the people who live to be 80 and 90, and for those who live only five or ten years, and even one or two years. Those who die of infectious diseases are also included in the average figure. No distinction is made between poor and rich, between the manufacturer, who knows no want and lives to a ripe old age, and the unemployed, who lives on meager rations and dies an untimely death from exhaustion and sickness.

Yet it is plain that if there were no epidemics and wars, if workers and peasants in all countries had good housing, rest, and normal working conditions, if their children were properly cared for and better fed, if there were no exhausting child labour, and if in all countries motherhood received state support, and medical services were within easy reach of all—that if all this were true, the average length of human live would climb steeply.

Conversely, epidemics and wars, and the exploitation of man by man with its attendant exhausting toil, unemployment and poverty, end men's lives long before they reach their normal physiological limit.

Social conditions under which all working people would have an equal right to healthy work, a full measure of rest, solicitous care in childhood, cost-free and skilled medical aid, and security in old age—such conditions unquestionably lengthen the average life span.

In the late 18th century the German physician Christoph Hufeland wrote a number of papers on longevity. His *Macrobiotics, or the Art of Prolonging Life* is particularly well known. In 1810 his followers founded the Hufeland Society, whose aim it was to propagate his ideas. In 1910 it celebrated its centennial. Its chairman, a Professor Hanseman, spoke at the celebrations. One would expect him to appeal for measures that would lengthen life. But he did the opposite.

He tried to prove that the fight for longevity is ill-advised, since the state has no use for old people, and that all efforts to cut down child mortality are irrational because it embodies the principle of the survival of the fittest. Hanseman also spoke of war, which carries away millions of lives. But he welcomed it as a "factor of selection"; in his opinion wars helped "strong races" to prosper.

Professor Hanseman was no anachronism. Even today views of that kind are being expressed in more or less covert ways by scientists in capitalist countries. Take the works of Professor Gratian, a specialist on social hygiene, which is a system of principles promoting the health of the popular masses. His *Social Pathology* appeared after the war. Gratian thinks that disease prevention and conditions under which even the sick could live long, would only lead to general degeneration, to humanity infested with "undervalued" elements.

William Vogt, whose *Road to Survival* appeared in New York in 1948, combines his official functions as director of the Pan-American Union Nature Protection Institute, with "scientific" pursuits. To Vogt the road to salvation is paved by disease, hunger, suffering, death, and war. He wants to reduce the number of the living. An increasing population, he says, is a major calamity. In spite of the war, the Nazi atrocities, and the under-nourishment, the population of Europe increased by 11 millions between 1936 and 1946, says Vogt, and deplores that the fascist killers destroyed, burned, and strangled "too few" men and women. He lauds Chile's high mortality rate as one of her greatest advantages.

William Vogt is not alone. Certain other bourgeois men of "science," such as the British biometrician Karl Pearson, Julian Huxley, Professor Meller, and many others, advocate the "benefits" of decimating the globe's population by all means including war.

The social conditions promoting longevity exist in the Soviet Union and in the People's Democracies. The reasons for this are plain. In the U.S.S.R. the exploitation of man by man has been abolished. There are no crises and unemployment, and all working people have a chance to lead a cultured and prosperous life. A far-flung network of prophylactic and medical institutions stands guard over public health. Mother and child protection, numerous maternity homes, crèches, milk kitchens, kindergartens, and state support to mothers of many children, have radically decreased child mortality and help to rear healthy and cheerful new generations.

This sheds light on the following figures. According to 1907-10 figures the average life span in Russia was 32 years. The census of 1926-27 fixed the mean figure in the Soviet Union at 44.3 years. Ten years of Soviet power were enough to raise the average longevity by more than one third. Yet the first five of them, with their civil war, blockade, and intervention, which brought on economic devastation, were a trying period in the history of the young state.

The 1939 census was not analyzed due to Hitler Germany's attack in 1941. But some of its figures are very eloquent.

In 1926 the population of the Soviet Union was 147,027,915. In 1939 it was 170,467,186. The increase was almost twenty-three and a half millions, a figure that greatly exceeds the total population of Sweden, Norway, Denmark, and Finland.

It reflects the rising birth rate, and the simultaneous drop in child mortality. It speaks of better living conditions, of a higher cultural level, of greater prosperity.

Public health and physical culture appropriations increase from year to year. In 1956 they totalled 35,000 million rubles, exceeding the 1955 figure by 4,500 million rubles. Every year new hospitals, maternity homes, dispensaries, and other medical institutions, sanatoriums and holiday homes, are opening their doors. In 1955 there were 60,000 more hospital beds than in 1954, while sanatoriums and holiday homes had accommodations for almost 14,000 more vacationists. New kindergartens, crèches, and children's medical institutions are under construction.

The Soviet state shows solicitude for the living conditions and health of the working people, children, and mothers. Children get proper care and adolescents get proper education. Suffice it to say that more than 5.8 million Soviet children spent the summer of 1955 at young pioneer camps, countryside homes and children's playgrounds.

HOW LONG ONE CAN LIVE

One side of the longevity problem is determined by social factors. But there is another side to it, which is based on biological laws.

A great many men live to be ninety, a hundred, and even more. The greatest number of people over a hundred live in the Soviet Union. The 1926 census placed them at about 7,000. Fifty-five of them lived in Moscow. Bulgaria was second with 158. There were 86 in Germany, 58 in Sweden, and 51 in Italy. In Norway, which is to all appearances a country of strong men and women, there were only 35 people of a hundred and over.

In 1937 the Ukrainian Institute of Clinical Physiology found several old men aged 130, 135, and 142 in Abkhasia. In 1936 mountaineer Khapara Knut died in Abkhasia's Ochemchiry District at 155. He had been the oldest man in the world. In August 1949 Vasily Tishkin, a Stavropol collective farmer aged 144, took a holiday at the Central Trade Union Council's Sanatorium No. 22.

Hundred-and-forty-eight-year-old Mahmud Bagir ogly Eivazov works at the Komsomol Collective Farm in Azerbaijan. In March 1956, when he celebrated his 148th birthday, he was awarded the Order of the Red Banner of Labour for his meritorious work in collective farming.

But many people live no longer than 80-85 years. Many more live only 60-70 years. And quite a few die at 45 and 50.

It is natural to ask how long a man could really live. Scientists have long been asking themselves that question. Buffon, who lived in the 18th century, proposed an original method of calculating the answer. He determined how long domestic animals grow by watching the growth of their bones. That was easy. An organism is full-grown when its bones stop increasing in length. A dog, Buffon established, grows two years, a cat—18 months, a cow—4 years, a horse—five, and a camel—eight, etc. He then divided the life span of each animal species by its period of growth. This yielded a mean figure of six, leading him to the conclusion that the life span of any higher mammal, including man, is five-six times longer than the period of its growth. According to him, therefore, man's normal physiological life span is 150 years, or six times his period of growth, which lasts about twenty-five years.

Academician Lazarev, the well-known Russian biophysicist, proposed an entirely different calculation. He tried to represent the periods of a body's development—its increasing vitality from the first years of life to its ultimate decline—in terms of numbers. He visualized them as a curve. By determining at least one section of it with mathematical precision he hoped to obtain the figures for the rest of it without particular difficulty.

Lazarev fixed upon the sharpness of the several sense organs as a criterion for the magnitude, duration, and degree of vitality in the body. He evolved a curve which represented the development of eyesight, hearing, and the sense of smell. He took account of the increasing keenness of perception as these developed, and their weakening and decline at the approach of old age, and in this way arrived at their extreme capacity.

Once he knew how much the sense organs decline with age, he was able to determine how much longer it would take them to become defunct. It was at that point, he concluded, that natural death should set in.

Lazarev's calculations set the viability of the sense organs at 150 to 180 years. He took the first of these two figures as typical for man's physiological life span. Lazarev's calculation, as we see, yielded the same figure of 150 years as Buffon's.

We must point out before we go any further that neither Buffon nor Lazarev discovered the laws governing the physiological length of human life. What they thought to be laws were really mere suppositions. Yet their guesswork contained some grains of truth, because other scientists, who each applied their own methods of calculating, arrived at similar figures. For this reason it may be indeed assumed that 150 years is close to the truth.

Lev Tolstoi, Turgenev, and Dostoyevsky could have lived in our day. Chaikovsky, Rimsky-Korsakov, Borodin, even Glinka, would today be writing new operas and immortal symphonies. Mendeleyev would still be active, and Pirogov would be witness and partner to the successes of Soviet surgery.

But that could only have been if people reached their peak age of 150 years. As a rule, man does not live to be even half as old. Unrepeatable life, life with its colour and its collective effort for the good of the country, its fruitful toil, its joys and loves and happiness, breaks off much earlier than is biologically ordained.

If death were not premature, it is likely that man would not suffer his parting with life as a tragedy. A long work day is always followed by a natural desire for rest. The same probably holds true for natural and timely death. After a long 150 years the fear of death probably evaporates. Death appears normal and welcome, while at present it is nothing of the sort. Even at a ripe age, in senile weakness, man hangs on to life desperately. His instinct for life is still strong, for he has lived only about a half of what he should live.

Why is longevity not possible even in socially favourable conditions? Wherein lies the cause of aging and premature death, when, biologically speaking, life should still persist?

LIFE AND DEATH OF CELLS

GENERALLY SPEAKING, man dies when his cells die, particularly those of the central nervous system and the most important organs. More precisely, man dies, but some of his cells are still alive. The hair and nails, for instance, grow some time after a person's death. At Professor Kravkov's laboratory, as we have said, fingers cut off from corpses continued to live. A fluid that was much like blood was passed through their vessels, sustaining life in them for a week and longer.

Experiments of that kind show that not all cells perish when man dies. Unfortunately, the cells that die slowly are of secondary importance to man. The most important are the cells of the central nervous system, and those of such internal organs as the liver and kidney.

But why do cells die?

The human cell must have normal metabolism, when all its particles are continuously renewed and the useless particles are removed. As long as nothing interferes with this, the cell is active and stable. If, on the other hand, metabolism is deranged, the activity of the cell grows weaker, and eventually morbid phenomena develop that may lead to the destruction of first one group of cells, and then other groups connected with the first, and to the destruction of tissues and organs. Morbid phenomena developing in one part of the body never remain isolated, and affect the vital functions of the entire organism. The organism, however, as a single whole, regulates the functions of all its parts through the nervous system.

CONNECTIVE TISSUE AND AGING

LONGEVITY AND THE CAUSES of death for long held the attention of Mechnikov, the originator of the phagocytic theory of immunity. He wanted to find a way of lengthening human life and sparing man a sad and painful senility. The vast experience and sagacity of old age would greatly contribute to the progress of science and engineering if men only lived longer.

Mechnikov studied the problem of longevity with his usual ardour. He fixed his attention on the most complicated organ—the brain. He made neat sections of the brains of corpses and examined them under the microscope. The picture was a familiar one: groups of nerve cells and their various offshoots, and between them, strata of connective-tissue cells. In some of them, however, there was an abundance of nerve cells and only small numbers of connective-tissue cells. In others the nerve cells were heavily outnumbered by connective-tissue cells.

There was nothing new, nothing unexpected in all this, nothing that researchers had not seen before Mechnikov. But he was chiefly interested in something else. He wanted to know the age of the dead people, whose brain cells he was examining. And that is where he came upon an arresting fact. The older the dead person, the greater the number of connective-tissue cells in his brain, and the smaller the number of nerve cells. It appeared that as man ages part of his brain tissue is supplanted by connective tissue.

The somewhat coarse and quite solid connective tissue forms a casing for the brain, and its strata are supports or bracings, as it were, which form something of a honeycomb to lodge groups of brain nerve cells.

Mechnikov also studied the liver and spleen, the arteries and the heart, and encountered the same thing everywhere. The differentiated, or, as he called them, "noble" cells of these organs, were supplanted with age by the coarser connective-tissue cells.

The conclusion was plain. As the brain cells grow less in number the memory weakens, the mental faculties wane, and the functions of the heart and other internal organs are thrown out of gear.

The function of the liver, spleen, and kidneys, whose cells diminish, deteriorates, and man grows infirm.

The cause of senility, according to Mechnikov, was to be sought in the replacement of "noble" cells by connective-tissue cells. The latter force out the "noble" cells because they have a greater capacity for growth, and that, indeed, conforms with the part they play in the organism.

A scar that appears in place of a wound, for instance, is nothing but abundantly multiplied connective-tissue cells. They weld together the edges of the wound, as it were. When a man falls victim to tuberculosis a part of his lung is destroyed, and scars appear, which are also connective tissue. A bullet perforates the muscles, and some time later connective tissue "patches up" the opening.

To be able to do that the cells of connective tissue must have a great capacity for multiplication.

As soon as the brain cells, and the cells of the liver, weaken and lose their vitality, stability, and powers of resistance, the cells of connective tissue multiply vigorously, supplanting the highly-differentiated elements of the organs and tissues. This replacement and thickening was defined by Mechnikov as the sclerosing of organs. He identified it as the cause of aging. The earlier organs began to sclerose, he said, the earlier came old age and death.

WEAPON AGAINST OLD AGE

THIS OUTLINE OF MECHNIKOV'S views is abridged and simplified. Nothing has been said of his views on phagocytes, the colourless blood corpuscles that devour worn-out "noble" cells. Nothing has been said of arteriosclerosis—the hardening of blood vessels which deprives arteries of their elasticity, and is caused by excessive strain, infectious diseases, alcohol, an unhealthy diet, and tobacco. Unquestionably, these factors have a great bearing on the process of aging. But this does not change the essence of things. In the final analysis phagocytes and arteriosclerosis are bound up with the aggressive nature of connective tissue, as this follows from Mechnikov's theory on sclerosing.

Mechnikov advocated physical culture and everyday personal hygiene, which prevent diseases that undermine the organism. He emphasized the importance of the diet, through which microbes penetrate into the organism most readily. He held that food should be boiled, cooked or fried, while fresh fruits and vegetables should be thoroughly washed in boiled water. Furthermore, he rightly thought that alcohol and tobacco should be entirely forgone.

Mechnikov thought these practices would safeguard the stability and resistance of the "noble" cells. He thought they would save them from the clutches of connective tissue. He regarded bacteria, legions of which are always present in the large intestines and cause the decomposition of the remnants of food consumed by man, as the most terrible enemies of the "noble" cell, because the products of decomposition are absorbed by the blood and reach the cells of the brain, liver, kidneys, and other organs, and gradually weaken them.

Mechnikov zealously propagated yoghurt, or Bulgarian sour milk. He said the many Bulgarians who live to the age of one hundred have yoghurt to thank for that, for it contains lactic acid bacteria, which prevent the multiplication in the intestines of bacteria of decomposition.

Proceeding from his theory Mechnikov sought to declare war on old age in practice.

He was perfectly right in saying that sclerosing brought on old age, that infectious diseases undermined the organism, and nicotine and alcohol damaged the blood vessels. He was particularly right about healthy habits. Yet Mechnikov failed to reveal the true causes of old age.

MONKEY GLANDS

THE FIRST REPORTS of Dr. Voronov's work appeared in the early 20th century in France. But Parisian physicians read them with reproof. When Voronov wanted to speak at a sitting of the medical faculty, he was refused the floor. The professors, who judged by the title of his report, thought it could not be serious and would only waste their time. It dealt with the transplantation of organs.

But eight years later things changed. His operations had won Dr. Voronov considerable prominence. His reports and lectures drew attentive audiences.

In 1912 a man who had come a long way, knocked at Voronov's door. He was a native of Bastia, Corsica, and had brought along his sixteen-year-old son Jean. The boy looked no older than seven. His face was puffed up, the colour of his skin was earthen, and his movements were languid and indifferent. He spoke like an imbecile.

Jean's thyroid gland was in the embryonic stage and practically non-existent. The thyroid gland is a gland of internal secretion, as distinct from glands of external secretion like, say, the salivary gland. The substances secreted by such a gland are known as hormones, and are discharged directly into the blood.

Even in negligible quantities hormones play an all-important part in the body. In the absence of the hormone secreted by the thyroid gland a child lags behind markedly in its growth, its mental capacities fail to develop, and signs of flabbiness appear, since metabolism is sluggish. The child becomes an imbecile.

The Bastian looked imploringly at Dr. Voronov. He had shown his son to countless doctors. They had shrugged their shoulders and said words of consolation. The ailment was incurable, they had said. It was impossible to create a new gland. But someone had told him of Dr. Voronov, who was interested in deranged glands of internal secretion. He was making experiments on rams and sheep. And so, said the Bastian, he had come with hope in his heart.

Voronov decided to try and give Jean what nature had denied him. But where to get a thyroid gland? No person would agree to give up his own. So Voronov excised the thyroid gland of an ape and implanted it to the boy. A year later Jean was attending school—an ordinary school for ordinary children. He no longer had the look of an imbecile. The ape's thyroid gland turned Jean into a new man.

The thyroid is not the only agent of internal secretion. There are four barely visible grain-like glands alongside it, which are known as the parathyroids. They govern calcium metabolism, and are one of the regulators of the nervous system. If they are removed, the victim soon has terrible convulsions, and dies.

Removal of the little glands above the kidneys known as the adrenals leads to death from insuperable weakness of the muscles, including the heart muscle, within two or three days.

The cranium contains a small organ weighing no more than half a gram. It is the pituitary body, a gland of internal secretion which plays an important part in the activity of the organism, and particularly in carbohydrate and fat metabolism, sexual development, growth, etc.

Far-reaching changes transpire in the body if the sexual gland is underdeveloped. A man does not perish from it, but his bones become thin, hair ceases to grow on the face, the muscles weaken, and the organism wears out rapidly; he may still be comparatively young, but looks aged, tires rapidly, and is languid, phlegmatic and indifferent. His memory is poor.

Meanwhile, the secretory activity of the sexual glands drops off with the years, and Dr. Voronov thought old age was the result of this lapse.

After the case of Jean of Bastia he performed more operations with the thyroid. And almost all of them were successful.

Was he ready to try another experiment: the transplantation of the sexual gland?

At first Voronov made the experiment on animals. He and his assistants performed hundreds of sexual gland transplantations in rams, bulls, and horses. As a result, the senile horses, bulls, and rams, indeed assumed a youngish look, and displayed the zest of young animals.

Now it only remained to utilize the acquired experience in operations on human beings. And Voronov began to transplant the sexual organs of apes into those who, like Faust, wished to redeem their youth.

His patients were silver-haired bourgeois, bankers, and lawyers who had reached the autumn of their lives. They faithfully informed Dr. Voronov of the results of the operation. Some did it a month hence, others two months hence, and others still in three and four months. All in all it transpired, they were well satisfied: they grew stronger, there was a general improvement, and their gait grew youthful.

That was what one of his patients wrote two months after the operation.

In another two months Dr. Voronov received a second letter. It was from the patient's son. He wrote that his father was found late at night at the door to his flat without signs of life. He had died of brain haemorrhage.

The zest of youth had come back to him, but the arteriosclerosis that affected his blood vessels, had remained. He had new sexual glands, but it was impossible to obtain a new heart and arteries, while his old heart and his diseased arteries were unable to cope with the strain.

Another patient of Voronov's had diseased kidneys. They failed to cope with the tide of new energy imparted by the transplanted sexual glands. The nephritis, an inflammation of the kidneys that developed on this ground, nullified the effects of the rejuvenation.

The other patients also reported things of a similar nature from time to time. The conclusion was clear. Sexual glands lend themselves to transplantations, provided the other vital organs are sound and have not undergone extensive sclerosing or other grave changes. But in old people these organs are usually considerably changed. Hence, a transplantation may improve the general state of the body for a certain period, but does not rejuvenate the entire organism. The weapon against old age proposed by Dr. Voronov was not effective.

AN UNSUSPECTED FRIEND

ACADEMICIAN BOGOMOLETS, a Soviet scientist, mapped out his own way of solving the problem of longevity.

He made a study of connective tissue, and discovered that its role in the body was very great.

Mechnikov had maintained that connective tissue was a foe of the "noble" cells. Bogomolets proved the contrary. He discovered functions of the connective tissue which were either unknown before, or, if known, failed to get the attention they deserved.

Connective tissue, as we said, supports the organs, serving the latter as something of a framework. This was thought to be their principal function. But that was wrong.

Cells cannot live without nutrition. Nutrition is brought to them by blood, and they absorb it through the extremely thin wall, the endothelium of the capillaries. The endothelium, meanwhile, is nothing but a variety of connective tissue.

Connective tissue possesses another interesting property: it produces a ferment capable of dissolving abnormal cells. These may be the cells of malignant tumours, for instance.

But that is not all. Connective tissue forms a reservoir, a vast "depot" of phagocytic cells that devour microbes.

A certain scientist dissolved Indian ink in water and injected it into the veins of a guinea-pig. Some time later he put it to death, and autopsied the animal, probing with the aid of his microscope the route of the particles of Indian ink after they left the veins. He found them in the liver, the spleen, the marrow, and in the lymphatic glands. And everywhere the particles of Indian ink occurred in the connective tissue of the internal organs. The connective-tissue cells had absorbed all the Indian ink that had penetrated into the blood. They filtered the blood, as it were, and removed from it all that was foreign and superfluous; Indian ink, in this particular case.

Properly functioning connective tissue ensures the normal functioning of cells, and this includes "noble" cells as well. Whenever the condition of the connective tissue deteriorates, it is attended by a deterioration of the "noble" cells. Sound connective tissue, in other words, means sound "noble" cells. Sound "noble" cells means a sound body, and a sound body means long life.

CAUSE AND EFFECT

From Bogomolets's point of view Mechnikov had wrongly assessed the significance of connective tissue in the body, and that led to other shortcomings in Mechnikov's doctrine on longevity.

He thought connective tissue gained prominence only when the function of organs changed or weakened, and that its role was hostile. The more marked the activity of connective tissue, he thought, the greater the danger to the "noble" cells, which it mercilessly demolished once their resistance dropped. According to Mechnikov "noble" cells may disintegrate and age, while connective tissue remains absolutely sound.

That was Mechnikov's first mistake. And it led to a second one.

Mechnikov meant to fight premature old age by fortifying the "noble" cells of the central nervous system, the liver, kidneys, heart, and the blood vessels, and to mitigate the function of connective tissue.

All he suggested to combat premature senility was meant to preclude harmful conditions, conditions that precipitate abnormal changes in the "noble" cells.

Apart from general hygienic measures to safeguard these cells from early wear and tear, he also sought medical means: an injection, for instance, that would invigorate and regenerate the cell function. In other words, he searched for a way to fortify the "noble" cells, while he should have searched for a way to fortify the connective tissue. It was this, according to Bogomolets, that was the prime failing of Mechnikov's doctrine.

Academician Bogomolets probed deeper and deeper into the properties of connective tissue. He wanted to find a way of stimulating its function. He suggested a special serum, which he called antireticular cytotoxic serum. It turned out to be highly effective in treating wounds (as an aid to healing) and certain diseases, both infectious and non-infectious. But the great hopes that Bogomolets's serum raised at first, were not justified.

A NOTABLE BLANK

BOTH MECHNIKOV AND BOGOMOLETS made a notable omission. They neglected the role played by the brain, or, more specifically, that part of it which is known as the cortex. This is confirmed by some startlingly convincing experiments performed at one of Pavlov's laboratories by Petrova, one of the great physiologist's closest associates.

Professor Maria Petrova spent more than thirty years studying the higher nervous activity. Through the years she conducted a great many experiments with dogs, and these produced interesting results.

She took robust, healthy dogs for one group of tests. The dogs were sound not only physically; their behaviour bore no trace of laziness, or excessive excitement. They slept soundly, and ran about the laboratory barking exuberantly when they awoke. They had a strong, untiring nervous system.

Professor Petrova put them in an experimental environment which continously stimulated their cerebral centres, "over-loaded" their cerebral cortex and provoked a state of ceaseless excessive excitation.

Kept in this state for several years, the dogs showed signs of over-fatigue. Their central nervous system was exhausted. They turned listless, languid and indolent, and ceased to react to the usual stimulants.

Symptoms appeared that even the experimenter had not suspected at first: the dogs aged prematurely. Their legs were weak and shaky, their joints thickened. Ulcers and sores appeared on their skin. Their hair dropped out and their teeth crumbled. They walked about with heads lowered and tails drooping. There was evidence of senile changes in their internal organs, and in certain cases matters went as far as malignant tumours. At twelve they looked a full twenty, and at thirteen or fifteen they died.

An environment conducive to disease of the higher nervous activity brought on premature old age.

A second group of dogs was treated differently. The dogs in this group had weak nervous systems. They were docile and good-natured, and tired rapidly. Although subjected to various protracted tests, they were given abundant and frequent rest. Nothing was allowed to irritate their nervous system and fatigue their brain. As a result they were blessed with a placid old age.

They lived much longer than the first group of dogs, and remained good-natured and satisfied to the end. Their hair did not lose lustre. They had no skin diseases, and at seventeen and eighteen they looked no older than ten.

Professor Petrova regulated the dogs' aging process, as it were. She delayed it by securing the normal function of the cerebral cortex.

Her experiments show clearly that all the vital processes in a body are regulated and unified by the brain, under whose influence they may either drop off, or intensify.

Petrova's findings throw new light on Bogomolets's theory of old age. His serum cannot, of itself, directly react upon the connective tissue alone. Its action is better understood if it is linked up with the central nervous system, in which it presumably provokes definite reactions. It is only through this all-embracing system that it affects the other organs and tissues, and, specifically, the connective tissue.

Petrova's experiments show that the central nervous system, and, principally, the cortical layer of the brain, play the most prominent role in aging processes. Whatever the causes of aging, it is manifestly clear that the state of the higher nervous activity, the proper function and interrelation of nervous processes, has a prime effect on the wear and tear of organs and tissues.

This was also proved on human subjects. There is a mental condition called schizophrenia, suggestive of serious neuro-psychic prostration. A schizophreniac is always tired, apathetic, frustrated, indifferent; he is too listless to dress, wash or shave. He has a look of intent concentration, and sits about with lowered head and faded glance. To look at him, he is the unhappiest person on earth. Senility and indifference hold him in their grip.

Bogomolets injected negligible doses of his serum into such patients. In many cases, if not all, there was a marked improvement. After a time some of them could be discharged from hospital. They were perfectly sound. Their recovery was doubtlessly caused by processes in the brain cells. No changes in the course of this mental disease could have transpired without the participation of the cerebral cortex. Hence it was only through the cerebral cortex that Bogomolets's serum had any effect on schizophreniacs.

All this goes to show that the cerebral cortex, with its functions of excitation and inhibition, is of the greatest significance in all the processes of aging.

Bogomolets and the other scientists who viewed old age as a result of changes in separate organs and systems had failed to take that into account. They ignored the fact that a body always reacts to all influences as a single whole, and that this oneness is due to the co-ordinating action of the cerebral cortex.

POSSIBLE SOLUTION

MEN ALWAYS SEEK LONGEVITY. Life always appears too short. No one wants to die. But men not only want to live longer: they want to live and stay young.

Goethe based his famous *Faust* on the legend of a doctor who sold his soul to the devil as the price for youth. All down the ages men suggested recipes to preserve youth.

Paracelsus, the renowned 16th-century physician, who had a tremendous store of knowledge for his day, sold a highly-priced potion which he called "elixir of immortality." While the buyer made use of it, he was supposed to be out of death's reach. How effective it was may be seen from the fact that Paracelsus himself died at fifty.

We have described only a few investigations by modern scientists who seek to find the causes of aging, and search for means to combat premature senility. The problem of longevity is much more complicated than it may appear.

ANOTHER SOLUTION

THE FIGHT TO PROLONG LIFE must begin long before the body has aged and lost vitality.

"The first principle of wise living is work," Bogomolets pointed out rightly. "The entire organism must work, and not a single one of its functions must be ignored."

Another prominent biologist said aptly: "Premature retirement from work... leads to premature old age."

Nekrasov, the great Russian poet and democrat, who branded the idle rich, said in his "Labour Song":

Whoever wants to be a fool
Must set himself the steadfast rule
To live in idle bliss.
A Hercules he may be born,
An intellectual tower,
Yet early he'll be weak and worn,
And, furthermore, a coward.

Mechnikov regarded fermentation and decomposition in the intestines as a source of self-poisoning, particularly if the diet consisted of low-grade foodstuffs and the bowels functioned irregularly. Products of decomposition, he maintained, continuously poisoned the cells of the body, including the connective tissue. To an extent this is quite true. Regular action of the stomach expedites normal digestion. High-quality foods and a varied diet limit decomposition; sour milk is particularly beneficial. The diet should not include too much meat. Physical labour should alternate with sufficient rest, precluding excessive fatigue, which exhausts the heart and affects the blood supply. Persons of mental occupations stand in imperative need of physical exercise. It promotes blood circulation and improves the oxygen supply to the tissue cells. K. Y. Voroshilov pointed out rightly that without physical exercise people doom themselves to old age at 45.

The body discharges much of its waste through the skin. The pores of the skin must therefore be kept clean. This means regular soap-and-water rub-downs.

Soviet people work with enthusiasm and a sense of creative inspiration, because they work for the good of their country. Soviet life knows instances of prodigal labour productivity. The sense of the importance of what they are doing stimulates the vital functions of the body. They are cheerful, lively, self-confident, and energetic. Under the circumstances, their nervous system and their muscles do not run the risk of over-exhaustion.

This implies a sound state of mind and sound work, which, far from exhausting the body, invigorate and fortify it.

Premature aging is prevented by a healthy diet and healthy habits, which stipulate physical exercise, fruitful labour, wise rest, proper personal hygiene, and a high cultural level.

But this way of life, in terms of the entire working population, exists only under the socialist system. The socialist system is the best solution of the longevity problem. It is the one and only way to lengthen life to its normal span, accomplishing what men have dreamt of all down the ages—a long and happy life with a natural and healthy old age.

However, a social solution of the longevity problem, does not rule out medical means.

MEDICAL AGE CONTROL

A CERTAIN MOSCOW POLYCLINIC specializes along very unusual lines. The people who come there on certain days of the week hardly qualify as patients requiring medical aid. They have no complaints: neither of ailments and pains, nor of weakness and prostration. They are perfectly healthy and fit, and work at various institutions in different, sometimes highly important, capacities.

At the polyclinic they are regularly examined, investigated by the latest exacting methods, and advised on their mode of life, on how to work, how and what to eat, and how to rest. If symptoms of a disease, unsuspected by the patients, are discovered at the examinations, they are treated on the spot or sent to a clinic.

All these people have only one thing in common—their age. They are all past fifty, all on in years, all on the threshold of old age.

The doctors examine them, and those whose organs and tissues already show changes, changes that are as yet slight and harmless but may turn into dangerous debilities if allowed to develop, are treated with the aim of arresting the process. This refers to persons with disorders such as high blood pressure, sclerosis of the connective tissue, thickening of the blood vessels, or atherosclerosis.

The doctors at the polyclinic are called upon to detect the incipient stages of these and similar debilities as early as possible. But that is only part of their job. The visitors are given precise instructions on how to arrest the development of morbid changes. Persons with early symptoms of a disease, are told how they must work and rest, and how to eliminate all harmful influences from their environment at work and at home. Regular examinations permit the doctors to control the loyal execution of all their therapeutic and preventive measures.

This is the first step of a remarkable undertaking aimed at turning the old age of people whose organisms already show signs of time's destructive action, into an unclouded and industrious period of their lives.

It is part of an offensive that is being launched in the Soviet Union with all modern medical means. The offensive does not confine itself to premature old age. Abkhasia has the greatest number of persons aged over 90—100. Since 1954 they have been taken under regular medical observation. Forty persons over a hundred, for instance, live in the Gagra District. One of them, Finnikov, aged 145, has been thoroughly investigated. Three old women, Mushkhudiani, aged 131, Barchiya, aged 119 (village of Koldakhvari), and Tabatadze, aged 119 (village of Pouskhevi), have been taken under medical control. Arkhip Kharibave, of Amokhadze village, is 127 years old, but insists on working at his collective farm to this day, although he is fully provided for.

Regular medical care will unquestionably lengthen the life of even these centenarians.

There are two kinds of old age. A man may grow old and lose his capacity not only for physical, but mental work as well. That is an invalid's old age, a pathological, or abnormal senility.

But there is also an active type of old age, when a man remains industrious and full of creative vigour in spite of his years. Pavlov, Mechnikov, Sechenov, and many other prominent scientists, such as Honorary Academician Gamaleya and Academician Zelinsky, lived to a ripe old age and remained full of vim and vigour to the last. They retained their capacity for work, their memory, and their vivid and profound intellect.

In the U.S.S.R. there are numerous collective farmers over 70, 80, and even 90, who insist on working in the fields, although the collective farm provides them with old-age security.

At Soviet factories numerous foremen and workers are long since getting their old-age pension; yet they remain at their post, working and instructing the new generation.

In the Soviet Union men of an active old age are builders of the new life. Their wealth of experience and knowledge, accumulated during their long life, are highly valued. The problem of longevity and an active old age is a problem of state significance.

The goals of the Soviet state—a high standard of living and culture for its working people and the building of a non-class communist society—are goals demanding a tremendous increase in productive forces, and the efforts of legion upon legion of conscious citizens. Every man counts and everyone does his bit.

According to the 1939 census men and women of sixty years and over constituted almost 12,000,000 or 6.6 per cent of the total population. That is a vast source of manpower.

The fight against premature old age adds millions of workers, physicians, engineers, artists, and specialists—mature, world-wise, experienced men and women—to the people of the Soviet Union. The country gains from this in material and cultural wealth. Mechnikov, that great fighter for longer life, dreamt of a state wherein "old age, which under present conditions is an unwanted burden, will become an active socially beneficial period. Old men, subject no longer to loss of memory and mental faculties, will be able to apply their vast experience to the most complicated and delicate tasks of social life." His dream is coming true.

CHAPTER SEVEN

LIFE STIMULANTS

COMPENSATION

IN FRACTURES OF THE LEG the doctor often has to remove bone fragments. The wound heals, the bone knits, but the leg remains shorter. The victim will limp the rest of his life. That is a pity, but the fragments have to be removed, because they prevent healing.

When a part of tissue is lost, as often happens to people wounded in battle, or to victims of various accidents, a big scar remains after healing. Yet a scar is not as good as the skin it replaces. Scar tissue bleeds easily, it is prey to sores and ulcers, and does not readily stand pressure. It is better than an open wound, but the protection it offers is worse by far than that provided by the original skin.

Boiling water, steam, and molten metal cause major burns. The burnt skin is replaced by scar tissue, and this often causes grave complications. Scar tissue is tough and inextensible. It may restrict the movement of the underlying muscles. It may cause contractures of the arms, legs or spine, crippling its victim.

Medicine seeks to prevent complications of this kind by means of grafts. If the affliction spreads beyond the skin to the subcutaneous tissue and muscles, the scar is excised and new tissue is implanted in its place.

Surgeons have long since learned to graft bits of skin taken from other people or from an unaffected part of the patient's own body. And whenever that is impossible, doctors take the graft from a corpse. Very often such transplantations prove effective. The new skin takes root, and normally performs its function. Soviet neuro-surgeons and physiologists have worked out the technique of grafting nerves. The nerve grafts are not taken from living people, of course, but from corpses or animals. Sometimes surgeons transplant small sections of the arteries and veins, and whenever operations for bone fractures cause a substantial shortening of the limb bone grafts are used to replace the removed fragments. Teeth are grafted. Sections of the intestines are used to substitute the gullet in cancer cases or in cases of strictures caused by burns or scars. By way of an experiment Professor Bogoraz has even replaced a severed dog's paw with a new one. It was a very difficult and painstaking job, but feasible nonetheless.

The technique of grafting grew to be near perfect. But there was one kind of transplantation surgeons always shunned, because it was hardly ever successful. It involved only about a square centimetre of tissue. Nor was it tissue seated in some inaccessible organ. On the contrary, it was surface tissue—eye tissue known as the cornea.

LIGHT AND THE EYE

THE CORNEA IS A BIT of transparent tissue which admits light to the interior of the eye, revealing to man the colours and the motion of the outer world.

There is hardly anything worse than loss of eyesight. However courageously men may stand up to the ordeal of eternal darkness, their inability to see is a bitter tragedy.

Nothing, not even the loss of hearing or any one of the other senses, can compare with the loss of eyesight.

Beethoven, whose entire life was bound up with the world of sounds, lost his hearing. It was a calamity to him, both as man, and composer. Yet he continued to write his immortal music. But an artist who loses his eyesight cannot paint any longer, however great his gift.

There are many eye diseases that cause total blindness. It often happens that eyesight fails because the cornea loses its transparency. This may be caused by an inflammation, or an eye sore.

Injuries of all kinds, and foreign bodies like microscopic metal dust, do great damage to the cornea. So do disease-carrying microbes. If treatment is delayed, a whitish spot appears on the cornea. Scarcely visible at first, it soon grows thicker, forming a wall-eye, or leukoma. It shuts out the light from the pupil. Rays of light fail to reach the back wall of the eye, or the retina, which is connected with the optic nerve. As a result, no visual sensation is transmitted to the brain. This is blindness. The eye itself is intact, but the fleck of opaque tissue shuts off the optic brain centre from the world, and turns its victim into a pitiful cripple.

At first doctors never thought that the sufferer could be helped in his dire plight. It was only in the 19th century that medicine tackled the problem in earnest. An interesting operation was evolved, which became known as an iridectomy.

The wall-eye shuts out the light from the pupil. An iridectomy gave the patient a new, artificial pupil, located near the first one, alongside the wall-eye.

The iris, which lends the eye its colour, normally contracts and expands to regulate the access of light to the eye. In other words, the iris is a diaphragm. The pupil is its opening, which admits light to the double-convex lens and retina.

The lens and the transparent cornea work together. They gather the rays of light, refract, and project them upon the retina with its optic nerve endings.

An iridectomy produces an artificial opening in the iris alongside the wall-eye. The cornea is incised in a spot where its transparency is unaffected, the iris is reached through the cut, and an opening is made in it.

The rays of light reach the pupil and lens through the new opening made under the cornea in the iris. But only a small portion of the light stream penetrates to the lens, and the patient's eyesight is far from normal. Yet even that is immeasurably better than total blindness.

Iridectomy was a boon to countless victims of wall-eye. But unfortunately it could not bring succour to all. Wall-eye rarely spares even a tiny edge of transparent cornea. It usually covers all the cornea, making iridectomy impossible.

ROAD TO SUCCESS

UNTIL THE MIDDLE of the 19th century doctors had no other method, outside iridectomy, to fight blindness. The blind whose entire cornea was affected by wall-eye, remained blind the rest of their lives.

The blind beseeched the doctors to return their eyesight, even if only partially. Furthermore, the doctors of that day did not regard the case as hopeless. They sought for ways and means to combat wall-eye. Both the patients and the doctors were aware that it was all a matter of the wall-eye, of that small opaque screen. Once that would be removed, light would pour freely into the eyes.

But it was impossible to remove the wall-eye. A thick scar would replace it if it were cut out. And a scar would be even more opaque. The aqueous part of the eye—the contents of the anterior chamber, and the vitreous humour—was likely to ooze out during the operation. Furthermore, microbes could find their way into the wound. The patient would lose his eyesight irretrievably. Wall-eye was the lesser of two evils.

Doctors were looking for some other treatment.

For many years oculists toyed with the idea of inserting something transparent, such as a piece of glass, into an opening cut in the wall-eye exactly opposite the pupil. Glass would prevent scars and would admit light to the pupil. Some of their attempts were extremely interesting.

In the fifties of the last century a blind man approached the German oculist, Dr. Salzer. The patient was not only insistent in his desire to see, he was also wealthy. He told Salzer to spare no expense. The oculist gave in to his persistent requests. He had long been thinking of artificial glass corneas, and had even experimented with animals.

A bit of rock crystal shaped as a tiny disc and set in a gold mounting, was to be used in the operation. Dr. Salzer incised the patient's wall-eye and inserted the mounted crystal into the opening, much as glassed window frames are inserted into windows. Sharp little horns on the sides of the mounting were meant to hold it in place. The crystal disc was removable from the mounting.

But all Salzer's pains came to nothing. The crystal irritated the eye tissue. A dull liquid formed under it, and it had to be continuously removed from its mounting to be wiped. The eye had to be washed. What was more, the crystal often moved out of place, causing the patient great discomfort. This lasted for two years. Finally the horns on the mounting lost their hold in the scar, and it fell out. All the patient's gold had not helped him. He remained blind.

Salzer's failure became known and doctors naturally gave up the thought of artificial glass corneas.

But the idea of removing the wall-eye at the spot of its greatest opacity, in the centre, and replacing it with something transparent, remained.

There was just one thing that could replace the wall-eye if it was not to be glass, and that was a healthy cornea. No other tissue in the body was transparent.

This led doctors to the idea of transplanting the cornea.

FADED HOPES

THE FIRST CORNEA transplantations were performed in 1865—66—almost fifty years after the idea was first voiced.

Thousands of people had impatiently waited for it. But they had to wait fifty years. The operation was much too difficult.

Almost nothing was as yet known about transplantations of eye tissue. Even the most brilliant specialists of the day had only a faint idea of the delicate operation on so tiny a piece of tissue as the cornea and so complicated and important an organ as the eye.

But that was not all. It seemed absurd to take the cornea of a corpse—dead cornea. Yet there was hardly a person alive who would give his cornea for the operation. At best, he would sacrifice no more than one of his eyes.

Furthermore, getting a bit of cornea was just part of the problem. It would have to be preserved after excision. Cut out tissue wrinkles. Cut off from its sources of nourishment it grows opaque. The doctor would have to graft opaque tissue that would not admit light.

Oculists of that day were aware of all that. That was why the idea of transplanting corneas appeared to be so unusual.

On learning of transplantations to cure blindness, one prominent early 19th-century surgeon, Diffenbach, exclaimed:

"That is the most daring idea ever advanced by a physician!"

Several experienced oculists tried to make cornea transplantations. Some made a great many. Among them were highly gifted surgeons, who designed special instruments to make convenient incisions in the wall-eye and cut out little discs of healthy cornea. They learned to make the graft take root in its new place. But they failed to return sight to the blind. After a while the transplanted cornea grew dim in spite of the surgeons' technique.

The cause was soon discovered. Surgeons used the wrong material for the graft. It was as yet unknown that animal tissues could not always substitute human tissues, and they took the cornea from rabbits, sheep, dogs, and hens. But nothing came of it even when they later grafted corneas from man to man. The reports of prominent specialists about their failures cooled the ardour of oculists for a long time to come. The hope kindled in countless blind people faded.

At the turn of the 20th century, when surgeons confidently transplanted skin, bones, cartilages, tendons, and even nerves, not a single oculist would attempt a cornea transplantation.

LIGHTS AND SHADOWS

In 1906 the medical world focused its attention on a report of a successful eye operation.

A cornea taken from another man's eye took root in the eye of a wall-eye victim and retained its transparency. The patient had perfect eyesight to his dying day. This was the only successful operation of its kind, but it proved beyond a doubt that cornea transplantations were feasible and effective.

The operation, performed by Dr. Zirm, naturally stimulated fresh research.

Zirm had not introduced any new elements into the operation. It was performed in the usual manner, and was nothing more than a stroke of luck. It was quite natural, therefore, that this isolated success was followed by new failures.

Two years later the Czech oculist Elschnig, one of the outstanding physicians of Europe, turned his attention to the transplantation problem. He worked out a new and better operative technique, introducing instruments that made the operation much simpler.

The number of operations increased. By 1931 Elschnig and his pupils performed 203 transplantations. But only thirty-one of them ended in complete success.

That was an unheard-of figure. It was no longer an isolated success. Medicine had performed thirty-one "miracles."

Up to 250 transplantations had been made by then in the United

States, Italy, and Britain. Fifteen per cent of the patients regained their eyesight.

Indeed, the cornea transplantation problem appeared to have entered a new phase. Science had made tremendous gains in its fight with blindness. Yet in the final analysis these gains were still attended by a tremendous number of failures. So complicated an operation could not pass without its share of failures, of course, but their great number was nonetheless appalling. Of 250 men who underwent the operation 215 remained blind. Many oculists were discouraged. They wanted to know why, with all things equal, some of the operations succeeded brilliantly, while others ended in dismal failure.

Then came news that astounded the oculists of the entire world. In the Soviet Union, where the fight with blindness was waged on a broad scale, success surpassed all expectations. A Soviet oculist, then Professor and now Hero of Socialist Labour, Academician Vladimir Filatov, had discovered the cause of the countless failures and found a way of preventing them.

VANQUISHED DARKNESS

The editor of a factory newspaper had eye trouble. The affliction grew from bad to worse. In the end he had to give up his job. One of his eyes, shrouded by wall-eye, was totally blind. The other was inflamed, and would soon fail. He was suffering from an eye disease known as parenchymatous keratitis.

The oculists he consulted could promise him nothing. Medicine was helpless against wall-eye. But they suggested that he try his luck at the Odessa Eye Institute.

That was in 1923.

In 1926 the blind man's sister brought him to Odessa. He could not see the face of the professor who examined him, nor could he make sense of what the professor said to his assistant, because it involved so many puzzling medical terms. But there was something about the professor's voice that filled him with hope, and there was also hope in what the professor said:

"Let's try an operation, a tissue graft. We'll do all we can."

The editor was operated upon a few days later. The next five days, which he spent in bed almost motionless, the bandage on his eyes was changed daily. Ten weeks later he was leaving Odessa for his home town, looking happily out of the carriage window at the blue sky and white clouds, the green fields, and the grey horse drawing a black char-à-banc, and at the striped lifting gates at railway crossings.

He went back to his editor's desk, and wrote regularly to Odessa. He wrote that his eyesight was good, and thanked the man who had returned him to light, work, and life. The address on the envelopes was: Odessa Experimental Eye Institute, Professor Vladimir Filatov.

A flier lost his eyesight. It was a terrible misfortune. To see boundless expanses from high up above, and then see nothing at all. To speed through the blue, and then move about cautiously with small, unsure steps, and cross the street with utmost difficulty.

An inadvertent blow had blinded the flier. There had been injuries, and scar-like wall-eye had formed on his eyes.

When he came to Filatov's institute in Odessa, he scarcely distinguished night from day. When he was leaving it several months later, he could see everything—even the number of the approaching tram a block away. He went back to his flying.

His letters to Professor Filatov from his native Sumy, said: "All's well. My eyesight is perfect."

Similar letters arrived every six weeks from a librarian in Zhitomir, who only recently lived in an impenetrable darkness. It had been all over for her. She was totally blind. But Professor Filatov's wonder-working hands returned her to normal life.

The unsuccessful operations grew fewer and fewer from day to day, and the stack of letters on Professor Filatov's desk kept growing. The letters came from the Far East, from sweltering Tajikistan, and from the cold North.

A HAPPY DISCOVERY

IN AN OPERATION FOR WALL-EYE the opacity is cut out, and a disc of cornea taken from some other eye, is put in its place. The graft may be taken from the eye of a dead man.

That is exactly what Elschnig and his pupils did. They thought that the sooner they could obtain a dead man's cornea after the instant of death, and the sooner they grafted it, the more chances they would have of success. Whenever they managed to get the graft an hour or two after death they were well satisfied. To them the cornea of a living person was still better. They got it from people who had no use for it any longer, people brought to the hospital with an eye socket damaged in a traffic accident, for instance, whose eyes were beyond repair. They had to be removed, but their cornea was intact, and could be used as a graft.

Elschnig and other oculists thought it was chiefly a matter of using living or only recently dead cornea, and of transplanting it with the utmost dispatch. Filatov rejected this point of view. He proved the contrary. The success attending grafts of cornea taken from living persons or fresh corpses was in most cases only temporary. The graft took root, but later grew dim. More often than not, the operation ended in failure. Only a few of the patients regained their eyesight.

Filatov did not use fresh cornea in his transplantations. In his opinion it was best to use grafts taken from corpses, and keep them for three or four days before the operation at a temperature of 38°-39°F. Long years of research had convinced him of that.

Elschnig, who used grafts taken almost exclusively from living people, restored eyesight to 31, or 15 per cent, of his 203 patients.

Filatov, who used dead cornea kept at a low temperature for three or four days, restored eyesight to 305, or 45 per cent, of his 671 patients. His results were three times as good as the results of operations with fresh grafts. What is more, his 671 patients included 294 inoperable ones. He gave way to their fervent appeals, and operated on them with practically no hope of success. If these 294 were not taken into account, the total number of operations would shrink to 377. The 305 successful operations would then constitute almost 80 per cent, which is five times as good as Elschnig's results.

Filatov discovered the superiority of grafts kept three or four days at a low temperature. It was indeed a happy discovery. There are at least fifteen million blind men and women in the world. Of these five million would probably benefit from a cornea transplantation.

The Russian scientist designed convenient instruments for the delicate operation, and worked out his own effective technique and method of operating. But the main thing was in the graft.

Grafts stored at a low temperature helped Filatov to restore the eyesight of almost all the blind people he operated, provided their eyes had not previously suffered irreparable damage.

It was an outstanding achievement, which wrote a glorious page into the annals of medicine.

A NEW CHAIN

FILATOV DEVOTED MANY YEARS to the fight with acquired blindness before he made his signal discovery. It had not been a mere accident. In his quest for a solution of the problem Filatov thought back to an example from medical practice.

Magito, the French oculist, had described an operation in which he urgently required a cornea for grafting purposes. There was no freshly removed eye at hand and he was compelled to use one that had been stored in the cold for a full eight days.

The operation proved successful. The stored cornea took root, and dimmed only slightly. What was more, its opacity soon disappeared, transparency returned to normal, and the blind patient regained his eyesight.

The French oculist described the case as an oddity. He had been sure that the operation would fail; it was the general opinion that success could only be expected with fresh cornea taken from living people.

But when Filatov read of Magito's case he adopted a different view. A true scientist, he felt that there was something of extraordinary importance behind this case, something that required deeper study.

The story of this successful operation turned Filatov's attention to circumstances that were ignored by the other oculists. His numerous experiments convinced Filatov that the case had not been a mere accident, and that stored cornea had its advantages. He applied his discovery to his patients, and soon won general recognition. His fame spread far beyond the borders of the Soviet Union.

It would appear that Filatov could rest on his laurels. But he was not only an outstanding doctor. He was also a scientist of unflagging energy. He wanted to know why a stored cornea taken from a corpse remained transparent.

It was when he helped more and more people to regain their eyesight, when it appeared that he had achieved all and could cease further quest and centre his attention upon perfecting his technique—it was then that he came to a chain of new brilliant discoveries of theoretical and practical significance.

STIMULANTS

FILATOV'S ASSERTION that fresh tissue taken from a living eye was less suitable in transplantations than stored tissue taken from the eye of a corpse, loomed as a paradox. All the oculists, and doctors of other specialities, asserted the very opposite. But Filatov supported his contention with proofs.

There was just one possible explanation. It appeared that certain substances were produced in the tissue of a dead person, which preserved it for some time. These substances took a few days to appear.

That was how Filatov reasoned. It was mere guesswork, but it was the only possible hypothesis. Filatov called them "biogenic stimulants," that is, substances which stimulated vital processes.

Tissue severed from the body does not die. It is not dead tissue. The hair and finger-nails of a corpse, for instance, grow long after death has set in. The tissue of a hen's embryo continues to grow for a long time provided it is placed in a nutrient medium. Even human tissue lives on. Kravkov's experiments with the fingers of a corpse are eloquent proof.

An eye removed from a corpse ten or twelve hours after death is not a dead eye. Living processes are not extinguished in it. Minute microscopic observations have discovered cell movements in the corneas of such eyes even five days after removal. That means the tissue is still alive. But its conditions are quite different from those in a living organism. They are much worse, and make living difficult, because the tissue receives no nourishment. Storage at 38^0-39^0F makes the conditions even more unfavourable.

But the tissue does not succumb to the adversities. It fights for life. Severed from the body, it adjusts the work of its cells; the latter produce substances which sustain the vital activity of the tissue under the new, unfavourable conditions.

The tissue may be fortified by increasing its resistance and stimulating its vital processes. The new substances appearing in the stored cornea, help its cells to live on. That was why Filatov called them "biogenic stimulants."

Experiments show that there are more stimulants in the tissue on the third or fourth day of storage than at any other time. This explains why cornea transplanted after three days of storage takes root so well and loses none of its transparency. It takes root because it is viable, and it does not lose its transparency because the invigorating effect of the stimulants helps it to surmount adverse conditions. As a result, the albuminous particles that form in the transparent cells and cause opacity, resolve.

Meanwhile, the eye tissue of a living person is less suitable for transplanting. It lives under normal conditions. It needs no stimulants, and produces none. Transplanted into a new spot, it is not prepared to put up a fight because it has not enough stimulants for the purpose.

That was how Filatov explained the paradox of fresh and stored cornea. He also explained what other oculists had observed, but did not understand: in successful operations the wall-eye that remained around the transparent graft also lost some of its opacity.

Filatov concluded that the action of the stimulants did not confine itself to the bit of transplanted tissue, but spread beyond its limits, reaching adjacent cells and raising their resistance. At the same time Filatov got to the bottom of another extremely important aspect of transplanting stored tissue—the activity of the stimulants.

His operation on a railway worker was particularly valuable in clearing up this point. The patient was totally blind after an eye inflammation. He had wall-eyes on both his eyes.

Professor Filatov first transplanted a new cornea to the right eye. The process of post-operative healing had to be watched and other treatment applied. Many days passed. At last the bandages were removed and Filatov was going to operate on the second eye. But he observed an unusual thing. There was only a dullish fleck on the second eye, where a solid, impenetrable wall-eye had been before. In other words, the wall-eye on the left eye almost completely resorbed of its own accord. There was no need any longer to make a second transplantation. This effect was achieved by the biogenic stimulants supplied by the graft of the right eye. The grafted bit of cornea was no bigger than half a finger-nail, and weighed about three grains.

It is to be presumed that biogenic stimulants act upon the various tissues through the nervous system. It is also likely that they act by humoral means, i. e., by means of the blood and lymph. That would mean that the stimulants of the tiny disc were absorbed by the blood and reached the left eye; their quantity, of course, must have been negligible. But even this negligible quantity of stimulants was enough to cause the resorption of cells in the opaque cornea. The stimulants are highly active. Filatov instantly assessed their potency and made bold, far-reaching deductions.

It was earlier thought that the purpose of grafting was limited to replacing one piece of tissue with another. Useless, damaged tissue—the wall-eye, for instance—was supplanted by a section of sound and normal tissue, which, once it took root, fulfilled its proper function. Nothing more.

Filatov, who studied the railwayman's case, discovered a new use for grafting. Transplanted cornea, it turned out, was not merely material that replaced the affected, opaque cornea. Over and above that, it had a healing effect on a diseased section some distance away from the transplantation—the left eye.

This could only be true if the biogenic stimulants performed their function in all the body, through the central nervous system.

But back to the conclusion drawn by Professor Filatov. The transplanted cornea is not merely a replacement. It is also a healing agent. The resorption of the wall-eye on the left eye under the effect of stimulants reaching it from as distant a source as the right eye, pointed to an absolutely new method of treating diseases.

EXPANDING BORDERS

THE CORNEA, IT TURNED OUT, is not the only tissue capable of producing stimulating substances. Other tissues also produce them. And that is only natural. All tissues are subject to the same physiological laws. Unfavourable conditions, under which they produce stimulating substances, may set in for any of them. In that case it should be possible to make any tissue do what the cornea transplanted to the railwayman's right eye had done in curing his left.

Filatov started with the cornea. In one of his cases he grafted it beside the wall-eye, and not in its centre. A bit later the solid wall-eye grew lighter. One more supplementary side transplantation followed, and the spot was altogether "erased."

Then Filatov did what would previously have seemed preposterous. He began treating wall-eye with transplantations of ordinary skin. He transplanted bits of conserved skin from the patient's arm to his temple, and in many cases this resulted in improved eyesight. In early cases, at least, the new method proved effective.

The skin is not directly connected with the cornea. If transplanted skin helped in cornea inflammations, it was likely to help in the treatment of other eye diseases. This inference was tested. Skin transplantations were performed in cases of retinal inflammations, inflammations of the sclera, and sympathetic ophthalmia—an extremely grave disease of the eyes; they were also applied in affections of the vitreous humour, atrophy of the optic nerve, cataract, and increase of intra-ocular pressure known as glaucoma. Although the new method was as yet applied on a limited scale, its success was obvious. In most of the cases it brought relief and arrested the morbid process. Cases of complete cure were sufficiently numerous.

After the skin it was the turn of the muscles, the liver, and the placenta. Bits of the organs were conserved, and then transplanted. A special type of transplantation, a so-called implantation, was applied in some cases; it was a graft of fragmented bits of the organs into the thick of the tissue; most often it was subcutaneous.

Biogenic stimulants do not confine their action to eye diseases alone. They stimulate vital processes in the cells of the skin, and in the mucous membrane of the stomach and lungs, and in the nerves. Stimulants raise the power of resistance of affected tissue and help it to survive.

A REMARKABLE FACT

THE BITS OF TISSUE USED as grafts are not taken from the patient himself, but from someone else, usually someone who died. They may introduce disease-carrying microbes into the patient's body. The temperature of 38^0-40^0F, at which the grafts are conserved, does not kill all the microbes even after five-six days. The danger of infection in transplantations, therefore, is quite genuine. What is to be done?

Let us recall how microbes are usually destroyed. Various disinfectants like, say, sublimate solutions or carbolic acid, are used for the purpose. Bur far from all tissues can survive the action of these disinfectants, which are poisonous substances. What is more, the disinfectants do not affect microbes that have made their way into the thick of the tissue, where the disinfectants are unable to penetrate. Materials are also disinfected in autoclaves. These generate a high temperature. Germs usually perish at 210°-250° F.

Disinfectants, which would destroy the graft along with the germs are unsuitable, and the autoclave, it seems, remains the only alternative.

In transplanting it is essential to use tissue which has been subjected to unfavourable conditions, but has survived them. Countless experiments show that these conditions are best produced by conserving the graft at a temperature of 38°-40° F. This temperature is best suited to the accumulation of biogenic stimulants. But germs die at 212° F. At this temperature the formation of biogenic stimulants will either slow down or cease altogether. Hence, the autoclave is also unsuitable.

After a persistent search, Filatov and his associates solved this problem as well. First of all, their research proved that many germs, including some of the most dangerous, perished at 38°-40° F if subjected to that temperature for six days. But that was not all. Investigating conserved skin and other conserved tissues, they discovered a remarkable fact. The strips of skin kept at 38°-40° F for four-seven days produced a great quantity of biogenic stimulants. After this the same conserved bits of tissue were placed in an autoclave and subjected for an hour to a temperature of 248° F. The investigators were certain that this temperature would destroy the biogenic stimulants, and only wanted to know to what extent this would be so.

The result of their experiment surprised them. The healing power of the biogenic stimulants remained unaffected. The biogenic stimulants were heat-proof. Meanwhile, no germ could survive a temperature of 248° F. Consequently, living carriers of disease were totally eliminated from the conserved tissue.

Another seemingly insuperable obstacle was thus surmounted. What is more, is was established that the number of biogenic stimulants increased at high temperatures. This may appear strange at first glance. But a thing is strange only as long as it has no explanation. New research showed, meanwhile, that storage at 38°-40° F causes the appearance of biogenic stimulants under the effect of biochemical changes. A part of these stimulants remain within the cells. After heating to 248° F the cells discharge the stimulants, and the latter's quantity increases.

BRIGHT PROSPECTS

EVEN THE DOCTOR whose business it was to cheer up his patient, could say nothing encouraging to the new woman patient, who came to the tubercular clinic at the Odessa Medical Institute.

The woman had had tuberculosis of the lungs for five years. The ailment had developed slowly, but surely. A hectic fever was exhausting her. She was weak and could scarcely speak, and was spitting blood frequently.

The doctors at the clinic discovered that she had particularly bad luck. There were tuberculous ulcers on her vocal cords and on the back wall of the larynx. In addition to lung tuberculosis, the patient was suffering from tuberculosis of the larynx.

No wonder the doctor failed to find words of cheer for her. What could he promise her? A miracle? But miracles do not happen.

Filatov, however, thinks that the doctor must never give up hope. He must always be an optimist. So when he learned of the virtually hopeless case, he instantly suggested his new method of treatment with biogenic stimulants.

On November 11, 1937, Filatov transplanted a bit of conserved skin into the patient's neck under the jaw. Three days later, when he came to visit her, she was having breakfast. The ulcers in her larynx were diminishing in size. Yet before that day she had not eaten properly for weeks because swallowing caused her unbearable pain.

A month later Filatov performed a second transplantation, and a third in yet another two months. The fourth transplantation was made in April of the following year. The patient's condition was steadily improving from operation to operation. Finally, in May 1938, the professor performed the fifth and last transplantation.

In June, having gained a bit of weight, the woman left the clinic. Her heavy breathing and cough had practically disappeared, and her temperature was down to almost normal. She had a good appetite, slept well, and was full of life, hope, and energy. She was convinced that she would get well. The biogenic stimulants of the skin grafts had done their job.

A printer with acute gastric haemorrhage came to the clinic of internal diseases in August 1938. The bleeding was so copious that doctors did not even venture to palpate his stomach, fearing to disturb the bleeding vessel. The cause of the bleeding was plain—stomach ulcer. An X-ray confirmed this diagnosis.

The ailment took a grave course. The bleeding resumed from time to time. The pains in the pit of the stomach, nausea, and heartburn, never ceased. And the hunger diet brought the patient to the end of his tether.

On October 1, 1938, a disc of conserved skin was transplanted into his subcostal section, and two days later his pains subsided. On October 10 he was discharged and went back to his work. He was only told to watch his diet and eat easily digestible foods.

But on January 13, 1939, the printer was brought back to the clinic. He had eaten too much lard and herring. That had apparently affected his fresh scar, and the disease took a sharp turn for the worse.

The patient had another transplantation. His condition improved the next day. And a bit later he returned to his work at the printer's shop.

An engineer had influenza. The influenza passed. But a complication—bronchial asthma—remained. He suffered from it for nine years. The attacks came almost daily. Strong smells, excitement, over-strain, dampness, cold weather, a sudden gust of wind—all this brought them on instantly. And often they succeeded each other at three- or four-hour intervals.

The engineer was treated with adrenalin injections. Sometimes this cut the attacks short, and more often it did not. His spleen was treated with X-rays. He tried electrotherapy. His nasal mucosa was cauterized. But all this had practically no effect.

On November 7, 1939, a bit of conserved skin was transplanted into his chest. His attacks of bronchial asthma did not cease altogether after the operation. But there were only two of them in six months, instead of the 180 that he previously had in the same period. The grafting operation was repeated. That was in March 1940. And his bronchial asthma never returned. At least it never returned in the sixteen months that the engineer kept in touch with the clinic.

Numerous other examples may be cited of cures effected by grafts of tissue of the skin, the peritoneum, placenta, and the cartilages. Lupus, ulcers of the shin, hips, and arms, furunculosis, peritonitis, delayed bone union after fractures, rheumatism, sciatica, burns, frost-bite, diabetes, and typhoid—were all relieved by grafting.

But the reader must not jump to conclusions. Grafting is not a cure-all. There have been numerous failures. Obviously, the condition of the organism, and many other factors, have a great bearing on this method of treatment, like on any other. In certain cases the very same diseases should be given other treatment. Medicine does not, and cannot have universal applications good in all cases without exception. This must be borne in mind to avoid undue hope and subsequent disappointment. Yet even isolated successes augur well. They show that the new method of graft treatment deserves note.

Filatov avers that the action of the stimulants does not confine itself to the focus of disease, and extends through the nervous system to all parts of the body, stimulating the protective resources of all the organs and tissues.

What Filatov often observed in his cases was, therefore, quite natural. And it was this: when the opacity on one eye was treated by the grafting method the eyesight of the second, sound eye would improve. That meant that even a normal eye benefited from the transplantation.

Not all cases of lung tuberculosis and not all forms of asthma, ulcers, and other diseases, can be cured by Filatov's method of tissue therapy. In spite of that, however, the method has a great future. It is as yet only a very young, but highly promising offspring of medicine.

The keen eye of a scientist saw through accidental and isolated facts to discover one more vital property of a living organism. He not only discovered it; he utilized it in the fight for man's health.

NO MYSTERY

THE NATURE OF THE BIOGENIC stimulants has not as yet been exhaustively probed. Yet there is much that is already known about them.

It has been determined, for instance, that they are not albumin. Neither are they enzymes, which have such great bearing on metabolism. They dissolve in water, and they are heat-proof.

Their chemical composition remained a secret for years. But in 1937 investigators received a substance from ordinary beans which they called dicarboxylic acid. It had the property of speeding the healing of wounds. When this was discovered people came to call it traumatin.

Later, another discovery was made. Conserved fish liver produces succinic and oxalic acids. These are classed as dicarboxylic acids. Conserved aloe leaves produce cinnamic and lacto-oxycinnamic acids, which are not usually found in aloe. Both these acids also belong to the group of stimulating acids associated with traumatin.

This sheds light on the nature of biogenic stimulants: they are substances of a definite chemical composition.

NEW HORIZONS

THE MAN TOSSES ABOUT IN BED. His pulse is irregular; it stops, re-appears, accelerates, then slows down again. To all appearances, the heart is making its final desperate stand. The temperature is ominously high. The patient gasps for breath. He is unconscious and delirious. His organism has battled with typhus for twelve days. Comes the thirteenth day and his condition deteriorates further. The mercury in the thermometer rises to the 106°F mark, and shows a tendency of rising even higher. The man's parched lips are cracking. His groans become weaker. His powers are failing, and at nightfall things look really black.

But in the morning of the fourteenth day the doctor finds the patient soundly asleep. He puts his hand on the patient's forehead. The fever has subsided. He feels the patient's pulse and finds it still somewhat fast, but regular. The heart functions sluggishly, but it is almost back to normal.

A light sweat covers the patient's brow, as though he has run a long way and is resting after a hard pull. Indeed, he has made the difficult passage back to life.

What happened to him during the thirteenth night is known as a crisis. A crisis is a turning point. The course of his disease turned. Before the crisis it was fast gaining in intensity, and after it came a sudden change, a turn for the better.

Disease is fought in more ways than one. Medicine is not alone in its battle. Within the body it has faithful allies in all the body's protective agents—antitoxins, antibodies, and phagocytes. If these win, the patient recovers. If they do not, the carriers of the disease take the upper hand, and the patient is lost.

Filatov added a somewhat paradoxical notion to this medical conception. Just before the crisis the patient's condition is the worst. This means that the body's protective agents are no longer able to cope with their enemy at that point. The organism breaks down. The patient's life ebbs away. But he does not die. There comes a sudden change. The onslaught of the disease subsides. It appears as though reinforcements have arrived in the nick of time to the aid of the body's protective agents.

Filatov identifies these reinforcements as biogenic stimulants. It is they, he says, that come to the aid of the exhausted organism at the eleventh hour. Approaching death creates highly unfavourable conditions for the cells of the body. Vital processes in the cells undergo a rapid change. The organism makes its last-minute efforts, as it were, to survive the rigorous, highly unfavourable conditions created by the disease. Biogenic stimulants appear in it as the last reserve of departing life. They range themselves alongside the protective agents, and give rise to a crisis.

If death did not come so close to the patient's bedside, there would be no vehement eruption of biogenic stimulants. The turn for the better in the course of the disease, therefore, is brought on by the approach of death. The patient recovers because he is on the brink of death. Filatov says that in just so many words. Whenever death is near, he says, stimulants appear, which are the last resort of departing life.

But man is only a part of living nature. The scientist who probes deep into the general laws of nature, wants to know if anything of the kind also occurs in other living beings—animals, birds, fish, insects, and plants. There is every reason to believe that it does. Here is an example.

There is a tropical plant known as aloe. It loves scorching sunshine. When it is kept in darkness—under conditions that are unfavourable to it—its leaves produce stimulants. This was proved quite easily. An extract was made from the leaves of aloe kept in the sun. This extract was introduced into an embryonic leaflet of another plant—the lilac. It remained unaffected. Its growth did not intensify, or slow down.

In another experiment the extract was from the leaves of a plant that had been kept in darkness for 25 days at 38°F—a temperature far below normal for an aloe. This extract was also introduced into an embryonic leaflet of the lilac, and produced a different effect. The lilac grew vigorously. It was plain that the leaves of the second aloe contained biogenic stimulants, while the leaves of the first did not.

And now a glimpse into Filatov's case records. Eighteen patients with inflammations of the cornea had hypodermic injections of conserved aloe leaf extract. These patients approached Filatov and his associates at different times in the course of several years. In some the complaint was more acute than in others. And in fifteen of them the injection had a beneficial effect. The inflammation subsided and was soon followed by full recovery. The stimulants in the aloe extract had brought them relief.

The intensified growth of the lilac and the recovery of Filatov's patients proved that an aloe placed in darkness and cold modified its vital processes to suit the new, unfavourable conditions. It also proved that any other organism—animal or plant—responds to the deterioration of its environment with similar changes, changes attended by the appearance in its tissues of new substances.

Let us now sum up everything that has been said before. Filatov's teaching on the cell struggling for survival with the help of biogenic stimulants, was built upon a comparatively minor operation—the grafting of cornea. Then it overstepped the sphere of eye diseases and extended to other departments of medicine.

It opened new horizons to medical science.

WORK IS A STIMULANT

WHEN PAVLOV STUDIED the function of the digestive organs he thought of an interesting operation. He took a dog's stomach and made two stomachs from it—one of them large, and the other small. All the food came to the large stomach, where it mixed with gastric juice, and was then conveyed to the intestines. No food was allowed to reach the smaller stomach. It was skilfully shut off from the first. It did not get its share of food, but whenever the dog was fed it secreted gastric juice. An opening was made in the smaller stomach, and a tube inserted into it, to collect this gastric juice, unadulterated by admixtures of food and of a composition identical with that of the larger stomach.

Pavlov wanted to investigate the gastric juice obtained from the small stomach and to learn what kind of juice there was in the larger one, and what happened to it when different foods were introduced.

Today this remarkable operation, which holds an important place in physiology, can be performed by any experienced physiologist. It was performed on several dogs at the Odessa Eye Institute. Gastric juices were collected from their little "Pavlov pouches." They were collected day after day, and it was determined how much juice was secreted by the "pouch" of each dog. The daily yield was stable.

Then came a sudden change. The yield increased sharply. The dog's diet was not changed, nor were the hours of feeding. But they all had a grafting of conserved skin. The biogenic stimulants stepped up the physiological functions of the body.

If two tadpoles have the rudiments of their hind limbs severed from their bodies, they will grow new ones. This process will be the same for both of them.

The Odessa Institute did this to two tadpoles. Their hind limbs began to grow, but in one of the tadpoles they grew much more vigorously, for it had been kept at a temperature of 39°F two days before the operation.

Two plots of similarly tilled land were sown to cotton. The yield of one plot was 20 per cent greater than that of the other, and, what was more, it ripened three days earlier. Prior to sowing the seeds used for the first plot had been processed with an extract of conserved aloe leaves.

All this proves that the biogenic stimulants in conserved tissues influence the entire organism, all of its functions, and all of its tissues. Moreover, it is self-evident that their effect on animals and men is achieved through the nervous system.

Athletes were objects of unusual and highly instructive experiments. And it turned out that there was a close connection between a foot race and biogenic stimulants. Filatov and his associates found this connection.

The eyesight of the runners was examined just before the starting gun. The race began, and after the runners crossed the finishing line their eyesight was examined again. It had become sharper. The scientists wanted to know why. The runners had not had any transplantations. They had not had injections. No biogenic stimulants had been introduced into their systems.

A simple experiment helped the scientists to get to the bottom of the riddle. After the race a few drops of blood were taken from one of the runners, and dissolved in water. The solution was injected into another person who had not run in the race, and had been sitting quietly in his laboratory. His eyesight improved.

Clearly, this happened because the blood taken from the runner contained substances that improved the eyesight. They must have appeared in the blood during the race—a product of intense muscular effort.

More blood was taken from the runners to determine the nature of these substances. Liquid extracts of this blood were tried in test subjects. The check-up revealed that their properties and effects coincided with those of biogenic stimulants.

This led to a new conclusion: work increases the output of biogenic stimulants. Work, therefore, is a physiological necessity, and is beneficial to the system. Filatov says that "by working not only mentally, but physically as well, a man tones himself up and raises his psychophysical level."

BROAD OUTLOOK

THE SCIENCE TREATING the eye and its diseases is known as ophthalmology. It was at all times a limited sphere, dealing with the eyeball, cornea, lens, vitreous humour, retina, and the posterior and anterior aqueous chambers, with diseases of the chorioid and conjunctiva, with intra-ocular changes in pressure, and with other pathological changes in the organs of eyesight. Eye specialists did not look beyond the world of ophthalmology. There was no need for it. It never entered anyone's head.

Filatov's works and his scientific world outlook have changed this view on the so-called restricted medical departments. He showed that the processes in eye tissues were identical to processes in all the other tissues, and that they were subject to the same physiological laws. The research of the Russian ophthalmologist showed that the optic organ also reflected the general condition of the entire system.

This means that there are no restricted departments in medicine. Every part of the body is connected with the organism as a whole. This, as we see, fully confirms Pavlov's postulates that the bodies of beasts and men are not merely sums of organs and cells, but are a single whole whose parts are connected through the nervous system. Filatov's medical practice testified to the fact that a doctor must not shut himself up in his special department, and that he must have a broad outlook in his conception of pathological processes. That is the reason why Filatov's own method went far beyond the confines of ophthalmology.

Filatov's teaching on biogenic stimulants and tissue therapy turned out to be very fruitful. It is applied at all medical institutions and clinics—neurological, surgical, skin, tubercular, infectious, ear, etc.

Tissue therapy has won unqualified recognition in the Soviet Union, and beyond its borders. Filatov's works are well known in the People's Democracies. Thanks to the Soviet scientist numerous patients in these countries find relief from suffering and illness. In March 1951 the Public Health Ministry of the Chinese People's Republic issued instructions to utilize Professor Filatov's method at Chinese medical institutions. In the major Chinese cities tissue therapy has been mastered, and is being applied with success for various complaints.

Filatov's teaching has followers in almost all the countries of the globe. And their number is rising steadily.

All this shows that the works of the remarkable Soviet ophthalmologist are an invaluable contribution to the fight against human debilities.

Certain features of Filatov the man are of great interest. He always says that there are no restricted departments in medicine, and his life's work shows that a genuine scientist does not confine himself to science alone, and that he does not turn his back on other aspects of life. Filatov is always busy with his research. He opens new horizons in medicine and biology. Yet he finds time to engage in public activities, reading popular lectures and writing articles. He likes fiction, and keeps abreast of it. He writes poetry, and handles the painter's brush with a great deal of skill. Judging by the numerous paintings hung on the walls of his study, the scientist in him has arrested the development of a gifted artist. Filatov is highly conscious of nature, and is a tireless hiker. His love of life, of men and nature, blends harmoniously with his deep devotion to science.

This trait completes his resemblance to such Russian scientists as Mechnikov, Sechenov, and Pavlov.

Academician Filatov is a worthy representative of the advanced Soviet science,

CHAPTER EIGHT

WHEN THE BRAIN SLEEPS

STRONG BRAKES

IN HIS *War and Peace* Lev Tolstoi describes the death of one of the book's leading characters—Prince Andrei Bolkonsky. The Prince was wounded in the Battle of Borodino, of 1812, and died a few days later.

The wound had been serious. It says in the book that the shell fragment tore through the stomach and hip. But in our day any qualified surgeon could have operated, and in all likelihood saved the patient. The operation would have been nothing out of the ordinary.

Prince Andrei did not die from the wound. He died from gangrene, or blood poisoning, which his doctor was unable to check. A keen observer and a master writer, Lev Tolstoi, painted a vivid picture of Bolkonsky's death.

In that same battle General Bagration was wounded in the hip. The muscles, nerves and bone were severely damaged. The surgeons treating the general knew that an immediate operation was needed to extract part of the shattered hip-bone and, possibly, a bit of the pelvis. It was a difficult operation, but in our day any qualified surgeon could have performed it. His surgeons, however, did not dare to attempt it. They knew all too well that it would not save the general. They knew gangrene would follow, and then death. They were helpless.

On January 27, 1837, the great Pushkin was fatally wounded in a duel with Dantes. The bullet penetrated into the bottom part of his abdomen. Today Pushkin would have had a laparotomy—his abdominal cavity would have been opened, the bullet extracted, the intestines examined for damage, and the wound sewn up again. Pushkin would have been fit within a month or two.

But Dr. Arendt, one of the most brilliant surgeons in Petersburg, who was summoned to the poet right after the duel, never even thought of an operation. And under the circumstances he was right. An operation was senseless. Gangrene was bound to follow.

Gangrene, or fatal blood poisoning, tied the surgeons hand and foot. They did not know at the time how to safeguard wounds from microbes. They did not even have a proper idea of what microbes were.

There was another equally disarming factor that handcuffed the surgery of that day. It was pain.

Tolstoi's novel has a few interesting lines concerning Anatoly Kuragin, another one of its characters. He had his leg amputated in the Battle of Borodino. While the surgeons operated on him a few burly assistants "piled on top of him," and held him down. Otherwise the operation would have been unthinkable. The wretch suffered harrowing pain, and struggled desperately under the weight of his tormentors. An amputation of the leg is a comparatively simple operation. It can be performed even when the victim writhes and squirms. But a major operation requiring utmost precision and care, such as an operation in the abdominal cavity, for instance, is out of the question when the patient twists and struggles from unbearable pain.

It is not only a matter of natural human compassion; the patient must be absolutely motionless during the operation. Otherwise it is inconceivable.

For many hundreds of years gangrene and pain tied the hands of surgery. The art of operating developed slowly.

That does not mean, of course, that doctors never tried to operate on internal organs. Internal operations—Caesarian section, for instance—were performed even in the dim past. All down the ages internal operations of all kinds were performed from time to time. But as a rule their results were sad.

No wonder the art of surgery was applied almost exclusively to a sphere best accessible to the surgeon's knife, the limbs. Doctors suggested new methods of operating, but their proposals chiefly concerned the arms and legs, face and neck, and only in isolated cases did they treat the chest or abdominal cavities, to say nothing of the skull.

The agonizing pain, the cries and pleas that attended operations made even the most self-controlled surgeons hurry through the ordeal without losing an instant. And that, too, hindered them from deliberating, studying, testing, and improving their surgical methods in practice.

A QUEST FOR SLEEP

THE ROOMS WHERE OPERATIONS were performed before the day of anaesthetics, looked more like torture chambers than hospital wards. Iron catches were fastened to the floor on both sides of the heavy table placed in the middle of the room, and strong leather belts were passed through them, while similar belts hung down from rings fastened to the ceiling. They were used to tie the patient to the table, so he could not stir.

During an operation the cries of the patient were heard several blocks away, and passers-by hurried to put as great a distance as possible between themselves and the house of agony.

The operating room was a ghastly sight. The patient and surgeon, and all the assistants, were spattered with blood, and there was blood on the walls and floor. The surgeons had either to be totally insensible to the patient's sufferings, or to have nerves of iron, and uncommon self-control. Only the most courageous of them ventured to perform operations.

Naturally, doctors searched for a way to subdue pain. It is said that Egyptian physicians knew how to make their patients unconscious. The juice of Indian hemp was known as an anaesthetic. Claudius Galen, the famous Greek physician of Pergamus, who lived in the second century, brewed a mandrake draught that induced sleep. A thousand years later surgeons used a sponge soaked in an extract made from poppies. The sponge was brought to the patient's nose and he was made to inhale the exhalation of poppy juice. He soon fell into a deep sleep.

But all this did not yield the desired results, and was only effective in superficial, simple operations, or brief operations that took little time. The patients had, nonetheless, to be tied down to the operating table, for the touch of the surgeon's knife usually roused them from their stupor.

All the efforts to find an agent that would really make man insensible to pain, an agent that could be controlled, extending or shortening the duration of artificial sleep, proved futile.

It was only in the middle of the 19th century that things finally changed.

TRIUMPH OVER PAIN

EARLY IN FEBRUARY 1847 PIROGOV, the famous Russian surgeon, was examining a patient. There was compassion in his eyes as he looked at the woman standing before him. She had to have an operation and go through all the harrowing torment of pain.

A second thorough examination led to the same conclusion. Her mammary gland was affected by cancer and had to be removed without delay. The removal of the mammary gland with all its adjoining lymphatic glands and nodules was a major operation involving an extensive area.

However, Pirogov was an experienced and highly skilled surgeon, and no one doubted the success of the operation. It was for him an ordinary matter. Yet the operation he performed on this patient differed greatly from the previous ones.

The assistants and students present in the operating room were struck with wonder. Pirogov was visibly excited and would not begin. He kept glancing impatiently at the door. His usual firmness and self-control appeared to have deserted him.

Suddenly an attendant of the hospital apothecary hurried in with a bottle of a colourless, transparent liquid. It was this that Pirogov had been waiting for. He snatched the bottle from the attendant's hands and approached the operating table.

"Do as I do," he told his assistant.

Pirogov poured a bit of the liquid on his handkerchief and brought it to the patient's face. A singular acrid smell spread in the room.

"Breathe deeply," Pirogov said, bending over the woman's head, "don't be afraid."

A few minutes later the woman was soundly asleep.

Pirogov told his assistant he would have to wet the handkerchief with the colourless liquid from time to time and put it to the patient's face. With that he handed him the bottle. Then he took up the knife and began to operate. He made incision after incision, but not the faintest groan came from the woman. She slept soundly.

The people in the operating room were astounded. Pain had not roused the woman from her sleep.

It was all over in two minutes. The operation was brilliantly successful. The patient was taken to her ward. And the first thing she saw when she awakened eight minutes later, was Pirogov bending over her.

"How do you feel?" he asked, his voice trembling with excitement. "Did the operation hurt?"

The patient looked with surprise at the bandage that covered her chest and shoulder, and raised her eyebrows.

"What? Have you operated?" she asked. "I did not feel a thing."

The surgeon straightened himself up. A look of deep satisfaction spread over his usually thoughtful, concentrated face.

That was how Pirogov first applied anaesthetic in an operation. It was sulphuric, or ethyl ether, whose action as a soporific had shortly been discovered.

True, a year or two earlier a chemical substance was found, which also acted as a soporific and pain-killer. It was nitrous oxide, or laughing gas. But its action was too brief. It was therefore applicable in only short operations, such as tooth extraction, for instance, or incision of carbuncles. Nitrous oxide was known as laughing gas because after inhaling it the patient at first experienced a sense of elation.

Ethyl ether was first applied as an anaesthetic in 1846, and nitrous oxide in 1844. In 1847 a new compound was introduced, which rendered the patient completely insensible to pain, however acute. It was a thick liquid, which came to be known as chloroform.

ROAD TO RECOGNITION

STRANGELY ENOUGH, agents that made man insensible to pain failed to meet general approval. Numerous doctors were dead set against chloroform and ether. They thought that anaesthetics ran counter to everything that existed since the Creation. What was more—and this was important—reports appeared that chloroform and ether brought on post-operative complications. Even fatalities were recorded. Nobody knew why they arose, and how to combat them.

That was why anaesthesia did not take root in medical practice. It was applied only in isolated cases. Most of the patients, meanwhile, were doomed to suffer pain and torment.

But matters took a different turn when Russian scientists, and particularly Pirogov, tackled the anaesthesia problem. He was the pioneer of the anaesthetic method of fighting pain in Russia.

That complicated operation for cancer of the mammary gland was followed by other operations. Their number multiplied. In March 1847 Pirogov advocated the use of ether in print, and described the cases in which he had applied it.

With typical scientific thoroughness he checked ether's effect on animals and human beings. He tried it on himself. But this seemed insufficient to him, and he was on a constant look-out for people who would volunteer to undergo tests.

Pirogov summed up his extensive clinical and experimental research in a comprehensive report published in a number of languages. The report contained important conclusions on the effect of anaesthesia on the human organism, and highly valuable practical directions. It was the first comprehensive paper in medical history on the application of anaesthetic ether.

Pirogov's works became known throughout the world and played a decisive part in promoting anaesthesia in surgery. Anaesthetics came to be widely used in all countries, and medicine stepped into a new era of great expectations. The works of the great surgeon were multiform in character and introduced many innovations to the art of anaesthesia. It was he, for instance, who perfected the technique of etherizing, and suggested a method which, in most cases, was of the greatest advantage. When he first heard of chloroform and studied it in practice at his clinic, he instantly perceived the merits of the compound, and the error most doctors made in using it. The chloroform-soaked handkerchief, he noted, should not be pressed to the lips and nose of the patient. It did not take him long to refute the general notion that chloroform acted better when used in a concentrated form. He proved that it should be diluted with oxygen, i. e., mixed with air. Diluted chloroform produced a restful sleep and caused fewer complications. Even after special masks supplanted the original handkerchiefs the Pirogov method remained law to all anaesthetists.

Pirogov has one more thing to his credit. He was the first to apply anaesthetics in battle conditions. That was in the Caucasus in 1847 during the siege of the fortress of Salta. Here is what he wrote in his "Report":

"Russia has outstripped Europe in showing the civilized world the indisputable benefits and possibilities of applying ether to the wounded on the field of battle."

In Russia Pirogov was not alone in his defence of anaesthesia. Other progressive Russian surgeons took his side. On December 9, 1847, Professor Pol, of Moscow, performed an operation with the aid of chloroform, and it was highly successful. In the Crimean War of 1854-55 not a single operation by Pirogov was made without the use of chloroform. The number of anaesthetics administered during the whole war was ten thousand—a fabulous figure for that day. After all, it was only the dawn of the anaesthetic era. This huge figure shows that Russian doctors were in the foremost ranks in this sphere of medicine as well.

The noted Russian physiologist Filomafitsky made a fruitful study of the effects of ether. His work had particularly important bearing on the fight with complications. It was he who wrote of contra-indications, or factors under which the application of chloroform and ether was inadvisable. Anaesthetics, he averred, could not be applied indiscriminately. In a number of internal diseases, such as affections of the lungs, liver, heart, etc., they were ruled out to avoid serious complications. Filomafitsky's studies of complications caused by anaesthesia saved countless lives.

Russian doctors worked out an efficient anaesthetizing technique. In his numerous operations Pirogov, for instance, had no fatal outcomes that could be blamed on the chloroform or ether.

Moscow statistics for 1896 show one chloroform death to about 6,000 operations, amounting to less than two-hundredths of a per cent, an amazingly small figure. And it spoke of the high technique of Russian anaesthetists. Nor was the importance of efficient anaesthetizing techniques ever underestimated in other countries. The skill of the anaesthetist often determines the outcome of an operation. It is only thanks to anaesthesia that surgeons today perform operations that were unthinkable in the last century. The surgeon has gained access to all the internal organs, and even the central nervous system. Anaesthesia has facilitated surgical progress. It stimulated surgery even in a day when the scope of surgical interventions was limited by the danger of infectious complications, subsequently eliminated by antiseptics and asepsis.

A DIFFICULT TASK

LET US RETURN TO THE DAWN of the anaesthetic era. Nitrous oxide was introduced as a pain-killer in 1844, ethyl ether in 1846 and chloroform in 1847. Thus, anaesthesia is a bit over a hundred years old.

Naturally, all types of anaesthetics have been investigated in that span of time. New anaesthetic agents appear from time to time, and are also subjected to a thorough screening.

The reasons for that are plain. The body is by no means indifferent to anaesthetic agents. In large doses they react violently, and even harmfully. They must be applied with great care. The technique of applying anaesthetics, the skill of making their smallest quantity go the longest way, is of supreme importance. Sometimes even a few extra drops may cause damage.

In studying and screening anaesthetics, investigators search for means to bring down to a minimum all possible danger to the patient.

At the same time they constantly search for new and better types of anaesthetics, and new and better methods of administering them.

Since the day when chloroform, laughing gas and ethyl ether were first introduced, there has appeared such a thing as local anaesthesia, which makes only the site of the operation insensible to pain. The pain is killed by an injection of novocain.

Then there is spinal anaesthesia, which, as it were, blocks the spinal cord at any desired point with the aid of a novocain injection. All the nerves governing the movements and sensations of the torso, arms, and legs pass through the spinal cord. When a part of the spinal cord is blocked, pain sensations from the affected parts of the body fail to reach the brain. To block pain impulses to the brain from, say, the legs, the novocain injection is made through the membrane of the spinal cord at the level of the lumbar vertebrae, while the abdomen is made insensible to pain by an injection at the level of the lower dorsal vertebrae. The higher the region of the operation, the higher up the spinal cord the injection is made. Under local or spinal anaesthesia the patient is not unconscious, yet he does not feel the pain. That is one more gain in the sphere of anaesthesia.

But all these methods of killing pain have their shortcomings. When the chloroform or ether reaches the respiratory tract the patient experiences unpleasant sensations of asphyxia and excitement, and a sense of dropping through space. And when he awakens after the operation, there is nausea, vomiting, a splitting headache, and other symptoms that sometimes last for days. Sometimes the aftereffects of anaesthesia are much worse than the aftereffects of the operation itself.

Local and spinal anaesthesia also have their failings when applied in lengthy operations. The administration or injection of the local anaesthetic takes some time. Besides, the patient experiences a sense of excitement and fear, and all the emotions attending the thought of being operated. There are cases when the patient faints before the knife touches his skin.

Scientists searched for an anaesthetic that would not have any of these shortcomings. Numerous anaesthetics were suggested in different combinations, with different methods of application. But every time the results were disappointing.

The problem was really extremely difficult. Scientists in all countries grappled with it, but it remained unsolved. Then the day finally came when the tables turned. This happened several decades ago in Russia. The solution was found by Professor Kravkov.

THE OTHER SIDE OF THE QUESTION

KRAVKOV WAS A PHARMACOLOGIST and studied the effects on the body of various chemical substances, and their possible application as medicines. He performed countless tests on animals.

That was also his aim when he tackled a compound known as hedonal. Hedonal is a hypnotic. It was prescribed against insomnia, provided the latter was not caused by severe pains, against which hedonal was helpless.

While testing its effects on animals, Kravkov injected a solution of hedonal into a vein. At that time the scientist was studying agents that would produce general anaesthesia by acting on the brain through the blood. He had already tried other compounds that caused sleep, but their effect had not satisfied him: the anaesthesia was either incomplete or of short duration, while an increase in dosage gave rise to toxic phenomena.

The experiments continued. They went on for months.

And hedonal injected into a vein turned out to be the boon people were searching for. Kravkov made note of scarcely visible signs—the movement of the chest and the respiratory rhythm—and others, that were pronounced and unmistakable, such as insensibility to pain, the pain reaction (dilatation of the pupil to a feeling of pain), and the condition of the animal after awakening. His observations led to the conclusion that hedonal yielded excellent results. The animal was in a state that largely resembled sound, normal sleep, and at the same time totally insensible to pain.

Further tests proved that Kravkov was not mistaken. Hedonal produced swift and lengthy unconsciousness, easily sustained through even the longest and gravest operations.

Now came the clinical tests. Professor Fyodorov, then one of the most prominent surgeons, lent Kravkov a hand. Fyodorov clearly saw what infinite advantages the new method possessed. The anaesthetic, introduced into the blood stream, went directly to the brain. The drawn-out procedure of general and local anaesthetizing, the mental anguish of the patient, and post-operative complications—all this would be avoided. If Kravkov's compound proved effective, unconsciousness would set in rapidly, within two or three minutes at the most. After the operation the patient would feel fine, almost as fine as after a sound sleep.

Hedonal was thoroughly tested at Fyodorov's clinic and then applied to man for the first time in medical history. It was injected into the patient's blood stream through the cubital vein. Two minutes later he was sound asleep, and slept quietly through the operation.

Kravkov's triumph was complete. It was all the more complete, because he had no forerunners. Thousands of people submitting to operations have him to thank for being spared the unpleasant, often highly distressing sensations that attended general or local anaesthesia.

As time went on other compounds were found which served with even greater advantage for intra-venous anaesthesia, such as pentothal, hexenal, etc.

But research has not stopped. Not only the agents themselves, but their effect on the patient's condition, and the condition of his separate organs, are being closely studied.

Chloroform, ether, and hexenal, and all the other anaesthetics, are liable to cause varying degrees of changes in the liver, kidneys, heart, spleen, blood, and brain. Scientists have to know what these changes are, and where they occur, how to prevent them, or to combat them when they do set in. They want to know how best to administer anaesthetics, how much of them to administer, what morbid changes in the organs are caused by the various anaesthetic compounds, and what new compounds yield the best results.

They did not go beyond that, however, and did not suspect at the time that anaesthesia could have other interesting aspects.

UNEXPECTED SURVIVAL

BEZREDKA AND EMILE ROUX—pupils of Mechnikov and Pasteur, the two great bacteriologists—devoted themselves to a study of mankind's invisible enemies. Roux, in association with Bering, found the diphtheria antitoxin, a most valuable agent in the treatment of that terrible disease. Bezredka developed Mechnikov's precepts on immunity and suggested a fairly simple method of preventing cholera, typhoid, and dysentery with special tablets. The latter contain dehydrated and greatly weakened, or dead bacteria.

Among the countless investigations and experiments made by Roux and Bezredka, there was one particularly interesting test.

A subcutaneous injection of several drops of serum taken from the blood of a horse was made to a guinea-pig. It would appear that the injection could not harm it. But the guinea-pig of Roux's and Bezredka's experiments jerked its paws convulsively after the injection, and died, as though the serum had been a quick-acting poison.

The few drops of serum would never have really harmed the guinea-pig. But Roux and Bezredka had taken a sensitized animal, an animal they had made particularly sensitive.

A few days before, they had injected into it a substantial dose of horse serum. Nothing had happened to the guinea-pig at the time, at least nothing visible. Yet the guinea-pig's organism underwent certain changes. It became sensitized, or hypersensitive, to the serum.

What was harmless the first time (the injection of an alien serum) was fatal the second time. The guinea-pig's organism became so sensitive to the serum that even a negligible quantity of it killed the animal instantly.

That was why the experiment with the guinea-pig ended so sadly. Instead of immunity, or the power of resisting the serum, the guinea-pig acquired anaphylaxis—an exaggerated reaction to the serum.

After some time Roux and Bezredka repeated the experiment. They sensitized another guinea-pig and again injected a few drops of horse serum. But this time the guinea-pig did not die.

The scientists prevented anaphylaxis. They did it with the aid of anaesthesia. They wanted to know how anaesthetics act in the presence of anaphylaxis, and injected the second, negligible but fatal dose of serum after the guinea-pig was given ethyl ether.

After inhaling the ether the guinea-pig sank into unconsciousness, and slept serenely on after the second, fatal dose of serum was injected. When the effects of anaesthesia wore off, it awakened, and its condition was quite normal. There was no death-dealing anaphylactic shock.

The investigators had discovered a strange phenomenon. Under anaesthesia the guinea-pig's organism unexpectedly lost its faculty of acquiring hypersensitivity.

ADAPTATION OF MECHANISM

AT THE LENINGRAD INSTITUTE of Surgical Neuropathology Professor Molotkov treated wrist oedema of various origin by surgical means. He dissected the nerve twigs leading to the wrist, and where all other conventional treatment—baths, electrotherapy, thermal therapy, and compresses—had failed, the oedema disappeared within 24 hours.

This was so utterly unusual, so superbly effective, that doctors who witnessed this treatment for the first time, were absolutely amazed.

The surgical reaction on the nerves apparently changed the conditions conducive to oedema. The dissection of nerve fibres cut the communications between the wrist and the central nervous system. This obviously neutralized the causes of oedema. Once the central nervous system no longer influenced the processes in the wrist, the oedema disappeared.

To prove this it is best to resort to an experiment. It must be an experiment which gives rise to oedema and simultaneously acts on the central nervous system. The experiment must be simple. It will then be convincing. The first part of it is easily achieved. An oedema may be artificially caused by, say, lewisite—a highly poisonous substance. A single drop of lewisite causes a visible inflammatory oedema in a minute or two, and a bit later the oedema gives place to a deep affection of the skin, even necrosis.

The second part of the experiment involves anaesthesia. In a way, an anaesthetic temporarily switches off the central nervous system.

Professor Galkin, of Leningrad, performed the experiment with lewisite at the Naval Medical Academy.

The experiment was performed on two cats. The thigh of each was shaved to bare a smooth stretch of skin. One of the cats was then given anaesthetic ether. It dropped off into unconsciousness. The other cat was not given ether. It served as a control. A drop of lewisite was applied to the shaved areas. In the case of the control animal an irritation appeared almost instantly, followed by a large local oedema. There was no such oedema in the case of the anaesthetized cat.

The experiment was simple and convincing. It confirmed that the central nervous system does influence the causes of oedema. At the same time the investigator was aware that his experiment had a deeper sense. It was perfectly obvious to him that under anaesthesia the skin did not react to an irritant, even a powerful one, like lewisite. But the skin is only part of a single whole, a part of the organism. This led to the conclusion that an anaesthetic was able to affect certain normal qualities of a body.

The effect was much the same as in Roux's and Bezredka's experiment with anaphylaxis. Only Roux and Bezredka went no further, and the Soviet investigator, Galkin, did. He and his associates performed a series of experiments which yielded quite unexpected results.

IDLE LEUCOCYTES

THE OEDEMA CAUSED by a drop of lewisite is the skin's reaction to an irritant. The anaesthetic deprived the skin of its power to react to it. But in an organism there are many other tissues and cells that react to irritations.

The blood, for instance, is highly sensitive. As soon as a person falls ill, particularly if the case is serious, his blood is tested without delay. The doctor wants to know how the blood elements react to the disease. Above all, he wants to know what happened to the white blood corpuscles, or leucocytes, and whether their number was increased and there is leucocytosis, or, conversely, whether it was reduced, and there is leucopenia. Both facts are important, for both have a certain bearing on the course of the disease.

Foreign protein is an acute irritant to an organism. If even a teaspoonful of ordinary cow's milk is injected subcutaneously or into the muscle, the temperature will rise, pain and irritation will appear at the point of the injection, aches will grip the body, and there will be a sense of general illness. The reason for this is plain. The milk contains a large amount of albuminous substances, which, absorbed by the skin or muscles, act as strong irritants.

But that is not all.

Take a drop of blood from a person who had milk injected into him, and examine it under a microscope. You will see a host of leucocytes. Instead of the usual 5—6 thousand to a cubic millimetre, there will be 10—12 thousand, perhaps even more. That is leucocytosis—white blood corpuscles mobilized to destroy the foreign protein.

High temperature and pain are visible and perceptible manifestations of the battle with the affliction within the body. Leucocytosis is the invisible reaction.

At Professor Galkin's laboratory milk was injected into the thigh muscle of a cat. A few hours later its blood was examined under the microscope. The quantity of white blood corpuscles had risen to almost 25,000 per cu. mm., while their number before the injection was 12,000, which is normal for a cat. The milk injection had caused an acute leucocyte reaction.

A second cat was given ether, and became unconscious. Thirty minutes later it had an injection of milk.

Three hours passed. During the cat's sleep its blood was examined several times, but no leucocytosis was found. Yet milk—foreign protein, an irritant—had been injected into its muscle. The injection was repeated several times, but the result remained unchanged. There was no leucocyte reaction. It was arrested by the anaesthetic.

The deduction was that organs producing leucocytes receive impulses, or signals, to step up the production of the protective elements, from the brain. And since the cerebral cells are "asleep" under the effects of anaesthetic inhibition, these signals are absent. No signals—no increase in the production of leucocytes.

TERMINATED CONNECTIONS

BOTH LEWISITE AND MILK ARE, so to speak, external irritants. They act on the organism from outside. But there are irritants that are produced within the organism itself; such as hormones, for instance.

Hormones are substances produced by glands of internal secretion—the adrenal, thyroid, pancreas, pituitary, and sexual glands. The blood conveys the hormones through the body, and they influence the function of the muscles, the blood vessels, heart, and brain.

Investigators wanted to know what happened to these internal irritants under the effects of an anaesthetic, whether their action was arrested and whether organs ceased to react to them. So they made use of insulin.

Insulin is a hormone produced by the pancreas, or, more precisely, by that part of it which is known as the islet cells of Langerhans. The word "insulin" itself comes from the Latin insula—island.

Insulin is essential to the organism. Without it man is doomed to die, and above all from exhaustion. He may consume great quantities of food, but the carbohydrates in it will not benefit his organism if it lacks insulin.

In the human body carbohydrates turn into glucose. In the muscles and liver the glucose turns into glycogen. On splitting, glycogen supplies the organism with energy. The nervous system and the muscles, for instance, cannot do without it.

In the absence of insulin, however, even vast stores of glucose in the blood cannot be utilized by the tissues. The glucose will then be conveyed by the blood to the kidneys, which will excrete it. There is always a certain amount of glucose in the blood. It comes from consumed food. Once insulin is introduced into the blood, however, its glucose content drops. The insulin obviously helps the organs to absorb the glucose from the blood and remake it into glycogen.

There is a disease known as diabetes. In diabetes the pancreas secretes too little insulin, or none at all. The sufferer can scarcely lift his arm or leg from exhaustion. There is an over-abundance of glucose in his blood, but no glycogen in his nervous system and little of it in the muscles. They have nothing to keep them going, for they cannot absorb the glucose without insulin.

As far back as 1901, Sobolev, a Russian scientist, gave voice to the following notion: by ligating the pancreatic duct it would be possible to isolate that part of the pancreas which secretes the hormone. Science must only find a way of removing the hormone and using it in the treatment of diabetes.

Here are Sobolev's words: "To date all efforts of treating diabetes by administering to the patient an extract from the whole pancreas brought no results. By ligating the duct, however, we now have a way of anatomically isolating the islet cells, and this will make it possible to utilize them in the treatment of diabetes." Sobolev indicated "newborn calves, whose islet cells are well developed," as the most suitable animals for this operation.

Twenty years later Sobolev's idea was used by Banting, a Canadian doctor. He isolated the islet cells of Langerhans in the pancreas of calves and extracted pure pancreatic hormones. Insulin treatment saves the lives of millions of people. The extracted hormone is injected into the diabetic, restoring the normal functions of his organism.

Professor Galkin injected insulin to cats. The content of glucose in their blood dropped instantly. It was intensively absorbed by the muscles in the form of glycogen. Then Galkin changed the procedure.

He gave cats great quantities of sugar, forming an excess of glucose in their blood. After that the animals were put to sleep with ether, and insulin was injected into them.

All the glucose remained in the blood. It was as though no insulin had been injected, as though there was none of it in the body.

It was there, of course, but the tissues did not react to it. The muscles behaved as though there was no insulin about. The anaesthetic ether had arrested their reaction to insulin. This led Galkin to the conclusion that the action of insulin depended entirely upon the central nervous system. That was why the "signals" of insulin failed to reach the tissues. The brain was asleep. Anaesthetic inhibition had switched off the signals.

POTASSIUM CYANIDE

FOR ALMOST A HUNDRED YEARS no one suspected the amazing phenomena that attend the application of anaesthesia. They were so amazing and novel that Professor Galkin and his associates checked and rechecked their experiments. The experiments were made on both men and animals. And all of them confirmed previously obtained facts.

One of the most interesting experiments was performed with hormones. Besides insulin the investigators took oestrogen, the hormone of the ovaries, and thyroxin, the thyroid hormone. They made very keen and complicated observations and analyses, all of which yielded similar conclusions. When the brain was switched off the action of hormones ceased. The hormones continued to reach the blood, but the cells of organs which usually reacted to them, ceased to absorb them. The cells ignored them, as it were. This upset all the previous conceptions about the mechanics of hormone influence on tissue. It was thought that hormones were "autonomous", and needed no intermediaries in their action on the various organs. Galkin's experiments, however, presented the matter in a new light: if the brain is asleep, the hormone is helpless, and though present in the blood it has no effect on the organism.

Yet the effect of even an insignificantly small quantity of a hormone is infinitely great. A gramme of insulin, for instance, would be barely visible in a spoon. But this single gramme can lower the glucose content in the blood of no less than 22,000 rabbits. While a single drop of oestrogen gives rise to certain sexual phenomena in 10,000 mice.

Such is the potency of hormones. At the same time scientists turn their attention to an important and interesting problem.

There is a substance of tremendous toxicity. It is known as potassium cyanide. It is one of the most potent poisons. It acts swiftly, and, in large doses, even instantaneously. It poisons all kinds of cells. Under its effect the cells cease to absorb oxygen; they stop breathing. If potassium cyanide is injected into the veins of a cat, it dies instantly as though struck by lightning.

Twelve cats had potassium cyanide injections. Six of them died one after the other within several seconds. But the other six survived, as though the injection had not been poison, but mere water. These six were under anaesthetic ether at the time of the injection. When the effects of ether wore off they recovered, none the worse for the experience. The anaesthetic had, as it were, tamed the potency of potassium cyanide. The highly poisonous solution seemed to have turned into a harmless fluid.

As a matter of fact, two of the six anaesthetized cats did die. They died when the effect of the anaesthesia ceased. That is an important factor. It reveals a significant aspect of the processes taking place in the body under an anaesthetic.

Let us go back to the leucocyte reaction of the body to a milk injection. Under an anaesthetic this reaction was absent. But what happened after the anaesthetic wore off? In some of the animals it disappeared. In others it did not. It disappeared in those who were under an anaesthetic no less than four hours. In those that slept a mere two or three hours, the reaction took place right after the anaesthesia.

The reaction indicates that the irritant, i.e. the milk, still remained in the organism. And since it was there, leucocytosis was a natural consequence.

In those, however, who had slept four or more hours the milk was broken down into harmless substances and, possibly, excreted.

In the potassium cyanide experiment the two cats died because they were brought out of their anaesthetic sleep too early—ten minutes after the anaesthetic had been administered. In their case the poison had not as yet left the organism, and their awakening was tantamount to death. The early termination of the anaesthetic gave the remnants of the potassium cyanide a chance to exercise its power to kill.

In the case of the other four cats the anaesthetic remained in effect until all traces of the poison had left the organism. This amounted to an hour. When the four cats recovered and ran about the laboratory, and when it was quite evident that they were in no danger, the investigators were wonder-struck. If they had not seen the experiment with their own eyes, they would never have believed it.

This gave rise to an important notion: the possibility of rendering harmless certain, even highly potent irritants.

THE EPILEPSY THAT DID NOT COME

EPILEPSY IS A DISEASE of the central nervous system, an ailment of the brain. An epileptic seizure sets in when excessive excitation takes place in it.

Upon reaching a certain intensity this excessive excitation results in a sudden loss of consciousness and severe convulsions of the body.

Under epilepsy certain irritating substances apparently invade the brain, giving rise to a severe reaction, a seizure.

It was quite natural that investigators should have asked themselves whether anaesthesia was able to prevent the reaction. After all, the irritation, its effect, and the termination of the reaction—all these processes were bound up closely with one and the same organ—the brain.

One series of experiments followed another. First of all, the scientists had to cause artificial seizures of epilepsy in animals. It turned out that camphor oil caused epileptic fits in animals. Injected into a cat, the camphor oil is absorbed by the blood, and reaches the brain. This is followed by successive seizures—20 to 24 severe seizures in all, which culminate in the cat's death.

There is another way. A solution of dried bile is introduced into the spinal fluid. This is done by puncturing the spine under the occipital protuberance. The bile soon gives rise to severe epilepsy with a lethal outcome after a certain number of seizures. This was repeatedly checked on cats and dogs.

Then the bile was introduced to cats and dogs that were under anaesthesia. The expected happened. Neither the cats nor the dogs showed signs of epilepsy. Even in the case of an absolutely fatal dose of camphor oil and bile there was not even a trace of it. There were no seizures during the anaesthesia, or after it, provided, of course, the anaesthesia lasted long enough.

The experiments yielded the desired results. But one more thing was discovered, which was just as important, and highly unexpected.

Continuous epileptic fits were produced in one of the cats. It died. Then the scientists examined the changes that occurred in its brain. They found that epilepsy caused considerable damage to the nerve cells. The cells disintegrated. Not all of them, but many, and not completely, but to a visible degree. It all depended on the duration of epilepsy and on the number of seizures.

That was very interesting and important.

If the cat suffered 6 to 10 seizures the changes in its cells were inconsiderable. In a cat which had had 14 to 18 seizures these changes were much more pronounced. And the damage done to the cells after 22 to 24 fits, i.e., just before its death, was even more so.

In one of the cats epilepsy was arrested after the eighteenth seizure. The animal was put to sleep by means of an anaesthetic. The cat slept for three and a half hours. It was then put to death and autopsied. It turned out that there were no changes in its nerve cells.

There is no doubt that the 18 fits had done damage to the brain tissue. But the three and a half hours of anaesthetic sleep gave the cells a chance to shake off the ill effects and return to normal. They were again able to live and perform their usual complex functions. There was no doubt about it.

It follows that anaesthesia does more than prevent fits of artificially produced epilepsy. Timely use of anaesthesia eliminates the ill effects of epilepsy and returns the brain cells to normal.

It seems that if the anaesthetic restores brain cells affected by epilepsy back to normal, it should also be able to restore the cells of other tissues affected by other diseases.

This matter, however, has not as yet been solved, but it is to be presumed that current investigations will provide the key to it.

REDUCED RESPIRATION

THE ANIMALS USED in laboratory experiments sometimes experience astounding adventures. A cat called Sobik once had to fly at a high altitude.

Sobik was a quiet, strong and enduring animal and was perfectly suited for the journey. But at a height of three miles it felt out of sorts. It began to show signs of unrest. Its respiration changed. It began to breathe heavily. But it could still move about; it was not as yet utterly exhausted. At the height of five miles it deteriorated rapidly. Its breathing became heavy, saliva flowed irrepressibly from its mouth and Sobik crouched miserably in a corner.

The altitude of six miles acted on Sobik with extraordinary severity. It could not stand on its legs, and dropped on the side. Cramps shook its body. The animal gasped for breath at long intervals, and at times stopped breathing altogether. At a height of seven and a half miles Sobik drew in some air convulsively, and stiffened.

Then came the descent. In eight minutes the cat was back on the ground, but its breathing did not return. Its heart did not beat again. Sobik was dead.

Sobik's ascent into the substratosphere did not take place in an aircraft or dirigible. It took place in a decompression chamber.

A decompression chamber is a room from which air can be pumped out, sharply decreasing its supply. The air may also be pumped back into it, when required. The air in the chamber can be made as thin as it is at any height above sea level; in a chamber of this kind living beings feel as though they have ascended in an aircraft to an atmosphere of just that particular density.

One can "rise" to any height without leaving the confines of the decompression chamber. Ten cats performed ascents of this kind. Some of them, like Sobik, died. Others survived. But they experienced severe discomforts for a long time to come, such as cramps, short breath, heart palpitation, and low blood pressure.

The investigators were not in the least surprised by these disorders of the vital processes. An insufficiency of air is inevitably followed by them in both men and animals. They are the result of an oxygen shortage and the change in the atmospheric pressure.

In the wake of the first ten cats a new group of twelve cats came to the decompression chamber. They were also made to "fly" to approximately the same height. But these new air travellers did not take their substratospheric voyage as hard as the first lot. They bore it well, and behaved at the peak of their "flight" just as they had behaved on earth. Their respiration was measured and rhythmical, and only at the height of seven and a half miles did it become somewhat heavier. Their hearts functioned normally all the time.

There was nothing to distinguish the second group of cats from the first. The "flying" conditions were just the same. There was only one point of difference—sleep. The second lot of cats slept during their "flight," having been previously treated with an anaesthetic.

Such was the principal experiment of anaesthesia under an oxygen deficiency. The experiment showed that sleep changes the reaction of an organism to a shortage of oxygen. But it did not end there. A few more details had to be determined.

Larger animals—dogs—were brought to the decompression chamber. There were two groups of them—six dogs in each. All of them made a substratospheric ascent.

Almost all the dogs of the first group died like the unanaesthetized cats before them. The dogs that survived could not get back to normal for a long time to come. But the dogs of the second group dozed serenely through their "flight," breathing regularly.

Yet they had not been plunged into deep anaesthetic unconsciousness. They had been given an ordinary soporific—luminal, medinal, or morphium.

Even these comparatively weaker sleeping drugs were enough to turn a dangerous trip to the substratosphere into a harmless jaunt.

NEW EXPOSITION

TOTALLY UNSUSPECTED implications of anaesthesia came to light one by one. Facts that previously appeared puzzling, or insignificant, came to be seen in a new light. They concern people, not animals, and therefore stand in need of a particularly cautious approach, but some of them are self-evident.

At his clinic Professor Bush had to deal with victims of various traffic accidents and railway disasters. He was not only a brilliant surgeon, but an observant scientist. He noticed that similar severe injuries affected some patients to a lesser degree than others. Bush wanted to know the reasons for this and discovered a strange fact. The injuries of accident victims who were brought to the clinic in a drunken state, passed lightly. Similar cases were noted at the Sklifosovsky Institute in Moscow, but no explanation was forthcoming.

The research conducted by Galkin and his associates threw some light on the matter. Alcoholic intoxication is an anaesthetic of a kind, and the latter changes the reaction of an organism to injuries and, consequently, reins in morbid processes.

In by-gone days doctors gave brandy to poisoning, or sepsis, cases. Evidently, they had noticed that this tended to mitigate the illness. We can say today that these physicians were well-advised in what they did.

There is an affliction known as the mountain sickness, which occurs in people who live at great altitudes. Its symptoms include discomforts in the chest, heavy breathing, weakness, and dizziness. It is caused by the thinness of air at high altitudes, and the resultant shortage of oxygen.

Professor Zhukov headed several expeditions to the Caucasus and Mount Elbrus. He noted that luminal is of great help in cases of mountain sickness. Luminal is usually prescribed to insomnia cases. It is a soporific. The professor had no idea at the time why luminal helped in mountain sickness. But we are hardly surprised by the phenomenon, since we know about the "flights" of animals in the decompression chamber. The drowsiness produced by luminal took the edge off the reaction of the body to the oxygen shortage.

Fifty years ago novocain was unknown. Local anaesthesia was then achieved by cocaine injections. Cocaine is a powerful agent which has harmful side-effects. Absorbed by the blood, it often gives rise to so-called cocaine poisoning, which is a fairly severe complication.

Heart medicines, or stimulants, or various other antidotes, were given to combat it. Some surgeons, who had accumulated extensive practical experience, instantly chloroformed the victims, and this brought rapid relief. The poisoning symptoms disappeared before their very eyes, as it were.

Surgeons made use of this effect, but were unable to explain it. Today we understand what they were unable to grasp. Anaesthesia, a preservative inhibition of the brain centres by means of artificial sleep, prevents the reaction of tissue to the poisonous cocaine.

Pavlov, the great physiologist, proposed to treat certain psychic afflictions with prolonged artificial sleep. Psychiatrists found that this was indeed beneficial. The benefits of sleep therapy should be clear to us. A prolonged, sound sleep arrests morbid processes developing in the brain. In such cases chloroform and ether are unsuitable. Sleep therapy is a lengthy process which may last for days, with brief intervals for meals, washing, and cleaning up. Chloroform and ether are too potent for this purpose. In schizophrenia, for instance, sleep is produced with ordinary and harmless soporifics such as luminal, bromide compounds, medinal, veronal or chloralhydrate.

These compounds may be applied five, ten, and even fifteen days running, to extend the patients' daily sleep to 15-18 hours. It is sleep of this kind that is beneficial.

Sleep under an anaesthetic and sleep induced by soporifics, have much in common. But there are also many points of difference.

At the moment we are interested in anaesthesia—a deep, impenetrable sleep which lasts as long as chloroform or ether are applied to the patient. It is distinguished from ordinary, sound sleep, which is brought on by the usual soporifics. It has its own features and its own properties. And these properties turned out to be highly unusual.

Associates of the Naval Medical Academy's laboratory of pathophysiology, who devoted themselves to problems raised by Pavlov, contributed substantially to the solution of these puzzling phenomena. They confirmed the primary role of the brain.

THE MAIN QUESTION

For almost a hundred years anaesthesia was valued only as a pain-killer. It was a blessing to those who had to undergo operations. But nothing more, no other properties, were attributed to anaesthesia.

Even Roux and Bezredka, who established the unusual power of anaesthesia to arrest anaphylactic shock, did not set great store by this remarkable fact. They were unable to delve deeper into the question, to perceive its essence, to grasp the prospects that it harboured.

A group of Soviet scientists, who were studying the vital functions in a diseased organism, tackled the problem of anaesthesia. It was then that new, highly important and extraordinary properties of anaesthesia were discovered. It turned out that chloroform, ethyl ether, hexenal, chlor-ethyl and chloralhydrate did more than just send the brain to sleep, and kill pain. It was confirmed that anaesthesia reversed many of the processes in the organism. Under anaesthesia it developed, the body ceased to react to many irritants.

It was not as simple as we described it. We gave an account of only the principal facts of the legion that were established and recorded in practice over a span of ten years. And these principal facts boil down to this: under anaesthesia the body's reactions to irritants, which act upon it through the central pathways of the brain, change, and so does the internal milieu of the organism.

And the main question, naturally, is: what practical value to medicine has this discovery made by Soviet scientists? Can this new feature of anaesthesia be utilized in the fight for man's health?

THE FIRST STEPS

A RATING WHO HAD SUFFERED severe burns was brought to the Naval Hospital. His pulse was quick, but very weak. The heart—unsatisfactory. The patient was in danger of shock, whose main symptom, as we know, is a drop in blood pressure and deterioration of heart activity. Other grave complications were also feared.

The moment the sailor was brought to the hospital was a crucial moment. The blisters had to be punctured and the affected area cleared of dead tissue. Steps had to be taken to prevent infection. But shock was imminent, and the scalpel would only inflict additional injuries. It could bring the shock nearer. The doctors faced a dilemma.

Then the surgeon anaesthetized the patient, and eliminated the possibility of shock. The anaesthetic prevented it.

To see the reasons behind this, we must visualize the exact circumstances. Shock, as we know, is the result of a painful blow dealt to the nervous system. The severe burns he sustained produced this shock to the sailor's nervous system. Shock is marked most acutely by a derangement and decrease of blood circulation. In the sailor's case the burnt area excreted large quantities of a thin, serous fluid—plasma. That meant that the blood was losing its fluid; in other words, it was thickening, and this, naturally, had adverse effects on the heart.

From the wound blood absorbed the products of disintegrated tissue. This, in its turn, only made things worse. That was why shock was almost inevitable. But anaesthesia blocked it. It did not prevent all the reactions of the organism to the burn, to its attendant pain, and to the absorbed products of disintegration, but it served to weaken them substantially.

To make better use of this anaesthetic effect, the hospital surgeon kept the rating under anaesthesia a bit longer than it took him to operate on the burnt area. He was pleased with the results. And, subsequently, whenever he had to deal with similar cases, he chose the same tried and true method.

The little eight-year-old girl who was brought to the clinic, had tetanus in an early stage. Tetanus, generally known as lock-jaw, is a terrible disease, fatal in the absence of a timely preventive antitoxin injection.

The doctor made a belated injection of the antitoxin into the little patient's vein. At the same time he treated the girl by means of anaesthesia. For eight days running he put her to sleep twice daily with the aid of hexenal.

In this case the only means to combat tetanus was anaesthesia. The treatment was terminated on the ninth day. The girl was out of danger, and there remained no trace of tetanus.

It is likely that in the sailor's case the shock was prevented, above all, by the fact that the anaesthetic killed the pain, and that the absence of reactions on the part of the organism played only an auxiliary part. It may also be presumed as a rare exception that the girl would have survived without the anaesthetic, and that hexenal only aided in her cure. But even then these two cases may be regarded as the first steps towards a new method, towards applying anaesthetics not merely as pain-killers, but as agents which act directly and decisively.

Steps of this kind are still few in number. They are still very timorous steps. And they are so unusual and amazing that doctors view them with a legitimate share of doubt. That is not at all surprising, for we must bear in mind that this highly remarkable discovery of Soviet medicine is still extremely recent.

AN INVASION

ANAESTHETIC SLEEP PRODUCES the desired effect in ever new cases, cases in which only recently the application of anaesthesia was not even contemplated.

Some forty years ago there was no such term as post-transfusion shock in the medical vocabulary. It came into being together with blood transfusions. When blood transfusions were first applied this shock was a frequent and dangerous complication. Nowadays it occurs only in exceptional cases, and in a much weaker form. Sound methods have been worked out to arrest the harmful effects, and even to prevent them altogether.

But today blood transfusions are being applied in great numbers, and even weak post-transfusion shocks are highly undesirable. They are a cause of great harm, and doctors are looking for new ways of fighting them.

But what, from the angle that interests us, is post-transfusion shock? It is a reaction of the blood serum to foreign red blood corpuscles introduced during the transfusion. That, at least, is what people thought previously. Pavlov's teaching offers a more accurate explanation. Incompatible blood is an abnormal irritant to the nerve receptors in the walls of the blood vessels. It gives rise to pathological impulses, which travel to the cerebral hemispheres and derange the normal function of the cells of the brain centres. This upsets the physiological processes in the body, the tissues and the organs—respiration, metabolism, and cardio-vascular activity. And that is post-transfusion shock.

In its sixth number for 1945 *Khirurgiya*, a Soviet medical journal, gave an account of some curious facts described by Dr. Khromov. He had made 100 blood transfusions with all due precautions. Of these 16 produced light post-transfusion complications. In other words, there were complications in one of every six cases. Then Khromov made transfusions to another 100 patients. And it turned out that not a single one of them suffered complications, or post-transfusion shock. This second group of patients had their transfusions made when they were under anaesthesia. The discomforts which, unquestionably, would ordinarily have been in store for many of them, were prevented by the anaesthetic.

The anaesthetic provoked protective inhibition in the brain cells. As a result, the impulses from the elements of incompatible blood that were inadequate and abnormal irritants, did not reach the brain cells, and were thus prevented from causing disorders in the physiological processes.

No wonder that some doctors, guided solely by experience and ignorant of Galkin's studies of the mechanics of anaesthetic action, put their patients to sleep with pantopon or morphium injections, before performing transfusions. These doctors were groping their way towards a new and promising path.

An amazing thing took place on the Leningrad Front during the war. In May 1943 a wounded soldier in a very grave condition was brought to a field hospital. He was instantly put on the operating table. The operation began. Just then his blood pressure dropped dangerously. And the surgeon decided to make a blood transfusion right there and then, while the operation continued. But it turned out that the conserved blood of the desired second group had all been used up, and two of the doctors instantly gave their own blood. Their blood was also of the second group. Three hundred and fifty cc were taken from each doctor, and the resultant total of 700 cc, a very big dose for a single transfusion, was immediately transfused to the wounded soldier.

Both the operation and transfusion were successful. There were no complications. The patient was making good progress. A few days later his condition was wholly satisfactory, and he was to be evacuated into the rear. But he looked pale and anaemic, and the doctors decided to make one more blood transfusion. They took a blood test to make sure of his group, this being laid down by the regulations for each transfusion, and were aghast with the result. They could not believe their eyes. The soldier, it developed, belonged to the third-blood group, and not the second. Yet on the operating table no less than 700 grammes of second-group blood had been transfused into him.

Seven hundred grammes of second-group blood is certain death to a man with third-group blood. It is not surprising, therefore, that the doctors were utterly confused. The patient had not suffered any discomforts.

On the contrary, the transfusion was followed by a marked improvement. For some reason incompatible blood had not done him in, but produced good results.

In 1943 the surgeons at the field hospital could not make head or tail of this phenomenon. But in 1944 it began to make sense. The remarkable and unexpected findings of Professor Galkin and his associates shed light on the case.

There are gastric ulcers and duodenal ulcers. They are treated in various ways. Often enough, for instance, gastric ulcers have to be excised; they may also be treated with a rest cure, a diet, and more often than not, by both at once.

But ulcers may be regarded as the upshot of a reaction of the intestinal tissues, by way of the brain, to some lasting irritant.

The clinic of Professor Chernorutsky, of Leningrad, has several very unusual wards. A permanent quiet reigns there, and there is not even the sound of a nurse's footfall. The silence is often so complete that it gives the impression that the wards are empty.

But they are not. Their inmates are undergoing treatment for ulcers by artificially induced sleep. Sleep prevents the reaction of the intestinal tissues to the irritant. This may help the ulcer to heal.

Sleep is protective inhibition. It prevents pathological impulses from the ulcer from reaching the brain centres; it therefore precludes all abnormal reactive impulses, which cause various derangements and thereby sustain the ulceration.

Such are the essential features of sleep cure.

We have already described how Dr. Negovsky worked out a remarkable method of fighting death caused by accidents. Negovsky's method is not only suited in agony, but even in cases of clinical death, i. e., when respiration ceases and the heart stops.

The Soviet scientist's method is a magnificent triumph of a bold and searching mind. But, unfortunately, Negovsky's method is not always successful. It is often late, because after five or six minutes clinical death is followed by biological death, and that is beyond help. Biological death is the disintegration of cells in the cerebral cortex. It is caused by the absence of oxygen and the attendant failure of the heart and respiration. Meanwhile, five or six minutes is not much. Help can easily come too late.

Yet the disintegration of cerebral cortex cells may largely be regarded as a reaction to a lack of oxygen. Experiments showed that dogs immersed in water in a state of anaesthetic sleep may be revived even after the time limit that holds true for drowned dogs under ordinary conditions. In the first instance the anaesthetic apparently decreased their requirement in oxygen, and they could, as it were, get along with what insignificant remainder of it was present in the tissues, without a fresh "supply." That postponed the moment of biological death. Anaesthetic sleep weakened and arrested the reaction of the brain cells to the oxygen shortage and thereby lengthened the duration of clinical death.

It may be justly presumed, therefore, that Negovsky's method, supplemented by ether or chloroform, will bring a person back to life even after the five or six minutes of clinical death have ticked out. Provided this assumption proves correct, a greater time reserve will reduce the number of cases when help arrived too late, and will improve the chances of saving lives.

The water hemlock, also known by its Latin name of Cicuta virosa, has its place in legends as the poison that cut short the life of Socrates, the famed ancient philosopher, who was made to take his own life while in prison.

The water hemlock occurs in the Soviet Union. It is widespread in the Urals, the Far East, the Karelo-Finnish S.S.R. and, to a lesser degree, in Moscow Region. Its root looks much like the root of parsley, and is often mistaken for it, and eaten. The result of such a mistake is fatal.

Doctor Ror works at a polyclinic in Verkhnaya Tavda, a Urals town. The water hemlock is often met in its neighbourhood, and victims of the murderous plant are quite frequent there.

In such cases Doctor Ror, like any other doctor would in her place, did everything in her power to save the life of her patient: she injected camphor and caffeine to stimulate the heart and respiration, she applied artificial respiration, administered tannin, and did everything else that could bring some degree of relief. But medicine is helpless against the Cicuta poison. And whenever a patient came to the casualty ward whose body was in convulsions, who foamed at the mouth, whose face was blue, who was unconscious and whose pulse was so weak that it could scarcely be felt, and whose breath was nothing more than a death-rattle, it was clear to the physician that his case was hopeless.

A patient was brought to Doctor Ror on July 7, 1947. He had eaten water hemlock. His respiration was weak, there was foam at his mouth and he had cramps at five-minute intervals. In half an hour, an hour at most, he would be a corpse.

But in six hours the patient was out of danger, and in another three days he was discharged. In six weeks, when Doctor Ror saw her patient again, she could scarcely believe that this strong-looking chap, who was the picture of health, had only recently been at death's door.

Doctor Ror had read of Professor Galkin's studies a few days before the hemlock victim was brought to her. She did not hesitate, therefore, to apply anaesthesia. There was nothing to lose anyway: life was fast ebbing in her patient.

The ether anaesthesia lasted six hours with brief intervals. When Ror decided that the poison had been expelled from the organism, she terminated it.

In July, August, and September 1947 three more Cicuta victims were saved in a similar way.

AN OPPOSING VIEW

When a person falls ill all that happens to him is viewed as a reaction of his organism to the cause of the disease.

The high temperature in influenza, for instance, means that the organism reacts to the stimulants of that ailment. Physicians regard a reaction of this kind in a positive light, for the high temperature shows that the organism has gathered all its strength to fight the bacteria.

When bacteria known as pneumococci invade a weakened organism, the victim falls prey to pneumonia. His temperature rises, and he is seized by a severe cough. The lungs thicken, and a thick fluid, an exudate, appears in them. All this is a reaction to the invasion of pneumococci.

It would appear that if there had been no reaction, the lungs would not be filled with exudate, air would readily enter them, the heart would have no difficulties in driving the blood through the pulmonary vessels, and there would not be any exhausting fever. The person would feel fit.

Therefore, the organism's reaction to the pneumococci should not be viewed as a positive thing, but as a negative, undesirable thing.

Which of these two propositions is correct? May it be said that the whole trouble hinges upon the reaction of the lung tissue to the invasion of bacteria?

There is an interesting observation from the animal world. The marmot is highly susceptible to plague, and dies quickly. But if it catches the plague in its winter sleep, it lives on and on. It dies only when it awakens. If the stimulants of plague could have been expelled from the marmot's organism while it slept, it would remain healthy.

That may hold true for any infectious disease in human beings, and not only for the marmot's plague.

The research of Professor Galkin and his associates brings us close enough to this conclusion. When the reaction is absent, it shows, there are no visible signs of disease. This inference obtains in any morbid condition, infectious or otherwise. Let us recall the experiments with cats and potassium cyanide. Should the tissue cells have reacted to the latter's action, death would have been inevitable and instantaneous. The absence of the reaction saved the cats from death. The experiments with high-altitude "flights" of cats and dogs, the case of the transfusion of incompatible blood, and observations of ulcer patients—all speak of the same thing.

It is plainly evident that the experiments with anaesthesia must amend our conceptions of certain morbid, pathological processes. But we must bear in mind that anaesthesia as a cure still stands in need of lengthy and thorough study. The picture is still far from complete. Sweeping deductions are premature. It is too early to apply anaesthetic cure to human beings, however promising it may be.

What is more, it should be kept in mind that anaesthetics themselves present dangers to the organism, particularly an organism worn out by disease. An anaesthetic may cause grave, even irremediable consequences, when applied to pathologically affected nerve cells.

So far all the work with anaesthetics has not gone beyond the walls of laboratories. It is still unfinished, and requires a great many lengthy investigations. But the positive results so far achieved by Soviet scientists give cause to believe that anaesthesia may become an effective agent against a great many human ailments.

CHAPTER NINE

THE VITAL LINK

A STRANGE OCCURRENCE

In 1940 Johnson, a millionaire, had a medical examination. His doctors, well paid by the financier, examined him with a studied thoroughness. The latest, most accurate methods were applied to investigate Johnson's heart, lungs, liver, the gastric tract, organs of internal secretion, and nervous system. All was in perfect order. Laboratory tests of his urine and blood showed that the millionaire was fit as a fiddle. Yet the doctors advised a change in scenery.

Smith Johnson really was in magnificent form. He had consulted the doctors and submitted to all their bothersome investigations only because he felt that a wealthy man should take care of his health. He viewed the summer trip prescribed by them as part of a millionaire's way of life.

Johnson set the date of his departure, but a sudden occurrence smashed all his plans. The stock exchange crashed. Johnson's stocks and shares slumped disastrously and were not worth much more than the paper they were printed on. He was ruined.

But that is not the point. Johnson experienced a physical weakness that could hardly be explained by his recent shock alone. He tired quickly, and climbed the stairs to his second-floor flat with utmost difficulty. He had a ceaseless agonizing itch, and an unquenchable thirst. And all these discomforts were gradually growing in intensity.

Johnson consulted a physician. This time it was not a millionaire's whim, but a matter of vital importance.

The physician did not need complicated and thorough investigations to determine Johnson's complaint. The diagnosis was sufficiently clear, and blood and urine tests confirmed his original conclusion: his patient had acute diabetes. That meant that the pancreas had ceased to function properly. Yet a mere fortnight before, when Johnson was examined prior to his projected trip, there had been no symptoms of disorder. The generously paid doctors and professors had thoroughly checked his health, the function of all the organs, including that of the pancreas, and had found nothing alarming.

Diabetes, which usually develops very gradually, broke out with unusual suddenness in Johnson's case directly after the crash on the stock exchange.

Could there have been a connection between the financiers' ruin and the function of his pancreas?

TWO TYPES OF CONTROL

A MAN WANTS TO INSPECT the façade of the house across the street, and raises his head. In a forest he feels like touching a tree and stretches his arm out, quickens his pace, squares his shoulders, and breathes deeply, filling his lungs with the delightful forest air. He is evidently pleased, and his face puckers into a grin.

All these are conscious acts that depend on the man's volition.

Volitional processes are governed by the central nervous system, by that part of it which is known as the cerebral cortex, or, more precisely, by centres known as the convolutions of the cortex. The cortex is also the organ of our mental life, the organ where our wishes, sensations, and conceptions originate.

But there is a wide range of processes in a body that are involuntary and unconnected with consciousness and volition—the functions of the liver, kidneys, stomach, intestines, and the endocrine glands, for instance, and a multitude of functions that have to do with blood circulation and metabolism. All these processes are of vital importance to the human and animal organism.

The nerves that govern and regulate these involuntary processes comprise what is known as the vegetative nervous system. It was previously thought to be an independent physiological mechanism, unconnected with our consciousness. That is why it is called the autonomic nervous system. Indeed, we cannot make our gastric juices increase or decrease in quantity, or the intestines to quicken their peristaltic motions, or the spleen to compress and the liver to produce more bile. All this is not subject to our will, and it was thought that the cerebral cortex, the regions of the higher mental activity, had nothing to do with such organs.

Two types of fibres—the sympathetic and parasympathetic—are distinguished in the vegetative nervous system. They differ, to a degree, in structure and function, but have a single purpose—to innervate and service the internal organs. Where the sympathetic fibres serve to intensify the activity of organs, for example, the parasympathetic decelerate and weaken them. And, conversely, whenever the sympathetic fibres inhibit an organ's function, the parasympathetic step it up.

The fibres of the vegetative nervous system do not extend to the cerebral cortex. They terminate in the subcortical centres. Previously, this served as anatomical proof that volition had no influence over them.

The case of the millionaire who developed diabetes after the crash on the stock exchange, could really appear quite mysterious. How mental strain could affect the pancreas and the supply of insulin seemed quite inexplicable.

A CONTRADICTION

THE DIVISION OF ALL PROCESSES in an organism into two independent classes—volitional, or conscious, and vegetative, or unconscious—has existed since times immemorial. And though science continuously progressed, many investigators held to this division until quite recently.

Yet there is a multitude of facts to prove the opposite. They show that the concept of two independent nervous systems falls out with numerous observations on both healthy and sick people. Mental distress, for instance, causes skin diseases, rash, and itches. Veteran physicians have seen their patients deteriorate under the effects of bad humour. Rising spirits, joy, and hope, meanwhile, are known to have had a healing effect. They appeared to eliminate bodily disorders.

Professor Kholtsov, the prominent urologist, could foretell who of his patients would be well sooner than the others. His students, and the author among them, were always astonished by the accuracy of his predictions.

"Well, how are you bearing up?" Kholtsov would ask when making the rounds of his patients.

"Fine, Professor," a patient would say with a forced smile, though he may have been operated only the day before and would still be in pain.

The professor would be pleased. Things would go well with this patient.

Meanwhile, another patient would dully reply:

"Awful. I feel sick all the time, and the pain is unbearable. Couldn't be worse".

There would be dejection and fear in his voice.

"This patient," Kholtsov would say on leaving the ward, "will be slow to get well. We'll have our hands full with him. Even complications are likely. He lacks the will to get well, he lacks optimism. A patient must have faith in an early recovery, then he'll really recover in double quick time."

And for the most part the professor was right.

All doctors have to do with diseases caused by auto-suggestion. A person who is always over-anxious about his health suffers one ill after another. He may eternally fear catarrhal gastritis and in the end he will experience a swelling of the abdomen, belching, and a heaviness in the pit of the stomach; next come loss of appetite and a resultant disorder of the gastro-intestinal functions.

Medical students first study diseases in their third year. When familiarized with the symptoms of various ailments they begin to grope within themselves, and examine their own sensations. More often than not they fancy themselves ill, and even consult physicians. Their complaints are known in the medical profession as "diseases of the third year." Curiously enough, physicians often actually find disorders in the organs of such patients. Their complaints are due to a sensitive imagination, fired by the description of morbid symptoms, and are really the effect of mental processes.

All this shows that practical medicine falls out with the former concepts of theory. In the past physiology asserted that the functions of organs of vegetative life were autonomous and independent from the cerebral cortex and its mental centres. Numerous observations indicated, meanwhile, that a relation between them exists and that, unmistakably, the cortex has a bearing on the vegetative realm of the body.

But those were only isolated observations. They alone were insufficient. It still had to be proved with precise and scientific facts, and experiments that the cortex really performed such acts and that it was a matter of a physiological law valid for all internal organs. And all down the ages scientists failed in their attempts to prove this.

In recent years Bykov, a Soviet scientist, took up the question of the relations between the cortex and the internal organs, the question raised by Sechenov and Pavlov.

LOOKING FOR A METHOD

THE BRAIN AND ITS HIGHER MENTAL centres is the most complex and most remarkable manifestation of human life. At all times it absorbed investigators who sought to probe the psychic activity and learn how it evolves and develops, and by what laws it is governed. The psychic problem has always been the most fascinating and difficult. The leading physiologists devoted themselves to psychic research. But in spite of important discoveries there remained numerous controversial and obscure departments. The famed Russian physiologist Sechenov made a revolutionizing contribution to the study of the human brain when he proved that psychic processes follow a pattern of reflexes. His notion put investigators on the right track and played a significant part in Pavlov's eminent research. Before Pavlov the study of the cerebral cortex yielded no visible results. The influence of the brain centres on the body's vegetative functions was particularly obscure.

At the time when all-important discoveries were being made to define laws governing the functions of almost all internal organs—liver, kidneys, heart, intestines, endocrine glands, and spleen, with their delicate mechanisms—the work of the higher regions of the central nervous system still remained a puzzle.

The lack of results is, above all, explained by the utmost difficulty of the task itself, and chiefly by the lack of a proper method of research.

The first clues to the riddle came to hand in the middle of the 19th century. Scientists opened a dog's cranium, removed the casing, and revealed the fissures and convolutions of the cerebral hemispheres. They wanted to know the whereabouts of the mysterious centres that govern the muscles when the animal wants to run, attack, or flee. The prime question was how to find them in the monotony of grey cortical matter.

The scientists utilized electric current. By irritating various points of the exposed brain with electricity they artificially induced contractions of certain muscles. Thus they discovered the connection between certain muscular movements and separate regions of the cortex. Other scientists applied the method of extirpation, or removal. They excised a bit of brain tissue and watched what would happen. The outcome was paralysis of various muscles. This showed that they had destroyed the centres governing these particular muscles.

The cortical centres of the sense organs were located in a similar manner. If the removal of given sections of the cortex was attended by the loss of hearing, eyesight or the sense of smell, this clearly showed their location.

The method of direct irritation and the extirpation method helped to determine brain centres governing almost all the muscles of the body and the sense organs.

Unquestionably, that was a major achievement.

But both methods had their failings, and these greatly limited their scope. They were applied on animals—dogs, cats, rabbits, and mice. The surgical operation they involved turned healthy animals into wrecks. The reactions obtained in the experiments were thus reactions of abnormal, pathological animals, while the aim was to determine the part played by the cerebral cortex in normal conditions.

What is more, the operations ruled out lengthy observations. Adhesions and scars would form, causing new morbid alterations. Meanwhile, brief observations lacked in the essentials—in the chance to determine the permanence of various phenomena.

Furthermore, investigators could only study the connections between the cortex and the muscles of the torso, head, and limbs, while the internal organs remained, for the most part, inaccessible. The relations of the cerebral cortex to the liver, kidneys, spleen, the organs of internal secretion, and the various tissues could not be revealed either by exposing the brain, or by extirpating separate sections of the cortex. The organs in question would have to be extracted from the abdominal or chest cavities, and manipulated, and this could not be done even by master surgeons without injuring the delicate, sensitive, and highly differentiated tissues.

Investigation methods that entailed extensive injuries could not yield the desired results. One scientist said aptly: "It's the same as investigating clockwork by discharging a rifle at it."

For that reason no real progress was made in the study of the higher centres of the brain, although physiologists could boast of isolated major achievements.

The Russian scientists Bekhterev and Mislavsky showed some 50 or 60 years ago that the cerebral cortex governs heart activity, salivation, the motions of the bladder, and body temperature, while Osipov, who was Bekhterev's pupil, found brain centres that influenced the activity of the large intestines. Those were weighty achievements for their day, which won their authors world-wide recognition.

But, again, the methods these scientists used—excitation of an exposed brain with electric current, crude chemical irritation of the brain, and removal of part of the brain tissue—could not give an accurate idea of physiological processes in a sound, undamaged organism. That is why the data obtained was controversial.

A special method of research was wanted, a method that would offer access to the most delicate, secluded, and deep-seated processes in the cerebral cortex and the internal organs, a method that would offer a chance of studying them in their normal, unaffected state, without causing the body visible injury.

A MODEST GLAND

His research in the work of the digestive glands won Pavlov world renown at the turn of the 20th century. His studies of digestion and the gastro-intestinal tract focused Pavlov's attention on a little organ of the digestive machine—the salivary gland. The salivary gland represented nothing unusual and mysterious. People had always known that it moistened the food in the mouth, and that saliva contained ferments—ptyalin and maltase—which acted on sugar-producing substances such as carbohydrates, and converted starch into dextrose, or grape sugar. It is this that produced the sweetness in the mouth when one chewed a piece of bread for any length of time. As soon as food was conveyed to the mouth it excited the endings of the lingual nerve, and caused salivation. It was an absolutely regular act of the automatic reflex type.

But in his experiments with dogs Pavlov's attention was drawn to something else: at feeding time the sight of food, be it only from afar, brought on salivation.

This was thought surprising in that day. The reflex action of the salivary glands should, as was then thought, follow the excitation by the food of the nerve endings in the mouth. In this case, however, there had been no excitation, but saliva appeared nonetheless.

That is what caught Pavlov's eye. Thousands of investigators had passed by this fact. The phenomenon appeared quite natural to them. The dog sees food, it wants to eat it, and this desire precipitates salivation. But this explanation did not satisfy Pavlov.

He studied all the processes attending salivation. It was not just a matter of food in the dog's field of vision, which roused its appetite. Pavlov made an amazing discovery. If a bell is rung on several occasions when the dog is being fed, the sound of the bell alone, without food, will eventually also precipitate salivation.

At first glance this may appear to be a very simple fact. But physiologically speaking it is extremely puzzling. The bell, after all, has nothing in common with processes of digestion. Why, then, does its sound trigger off the salivary gland?

There was just one explanation. When food reached the mouth saliva appeared because that was an inherent function of the salivary gland. That was an inherent reaction, or, as it is commonly known, an inborn reflex. The bell also caused a reaction of the salivary gland. Hence, that was also a reflex action. The reflex was formed by repeated preliminary synchronization with the inborn food reflex. Therefore, it is not an unconditioned inborn reflex, but a reflex evolved artificially. Pavlov called it a conditioned reflex.

The excitation caused by the sound of the bell, or, to put it another way, conditioned excitation, was received by the hearing organ and transmitted to the brain along the acoustic, or auditory nerve trunk. The impulse excited the brain cells and spread throughout the brain cortex. Pavlov called this phenomenon irradiation.

In the dog's case it had been repeatedly associated with the unconditioned excitation caused by the sight of food, and was transmitted with it to the salivary centre. When it was eventually applied alone, unsupported by the food reflex, it also took the habitual road to the salivary centre, excited it, and precipitated the function of the salivary gland.

This was, naturally, the simplest possible combination. Infinitely more complicated conditioned reflexes may be formed, bringing on much finer and more sensitive reactions in the cortical centres.

The discovery of conditioned reflexes was a triumph in brain physiology, and the conditioned reflex method of research—an efficacious key to the secrets of animal and human behaviour and psychic processes.

DISPLAY OF INHIBITION

PAVLOV AND HIS NUMEROUS ASSOCIATES made countless experiments, gradually lifting the veil that shrouded the mechanics of the higher nervous activity. After they had studied excitation processes, they tackled inhibition, an all-important function of the cerebral hemispheres. The significance of inhibition was revealed in numerous experiments, one of which, made several times at Pavlov's laboratory, was particularly interesting.

If the experiment with the bell is extended, and the bell is sounded several times running without food, i.e., without being backed by unconditioned excitation, the quantity of saliva will diminish from one time to the other, and salivation will finally cease altogether, no matter how long the bell is rung. The conditioned reflex will fade.

It took several years of unflagging effort to determine why conditioned reflexes disappeared. It was inhibition in the cells of the cerebral hemispheres that terminated them. An experiment made by Krasnogorsky, Pavlov's pupil, confirmed this. A little pinprick device that irritated the skin was attached to a dog's hind leg just above the paw.

Another such device was attached about an inch and a half above the first, and a third—about eight inches higher, almost on a level with the knee.

Conditioned reflexes were then evolved for all three devices. They were applied whenever food was administered. After a few such associations of pinpricks and food, saliva ran freely when the devices were applied without food.

After this the bottom device, attached above the paw, was applied without food. The flow of saliva diminished from one time to the other. Finally, it vanished altogether. The conditioned reflex faded. All subsequent applications of the device did not yield a single drop of spittle.

But in the case of the other two devices, whose application was still backed by food, the conditioned reflex remained intact.

The stage was set, and the investigator passed on to the experiment proper. He again applied the bottom device, attached just above the paw. Just as he expected, it did not provoke a single drop of saliva. The second device, meanwhile, applied a minute later, caused a substantial flow of it. But when applied once more in another three minutes, it yielded nothing—not a single drop.

This was amazing. Just three minutes before the second device caused considerable salivation and the conditioned reflex worked splendidly.

Five seconds passed, and there was no response. The conditioned reflex had disappeared. It was now the turn of the third device, attached quite far from the paw—a full eight inches up the leg. When it was applied saliva flowed freely. But no more than fifteen seconds later the reaction vanished. The conditioned reflex did not respond.

Unbacked by food, the repeated application of the bottom device, which irritated the skin, brought on a reaction of inhibition instead of excitation. That caused the conditioned reflex to disappear. But the process of inhibition did not stop at its site of origin and spread throughout the cerebral cortex. It reached the brain cells whose excitation was geared to the conditioned reflex of the second device. In another fifteen seconds it spread to the brain centre linked with the irritation caused by the topmost device, and the conditioned reflex of the latter vanished as well.

This was as clear as if it were being shown on a screen. In watching how salivation attending the application of the first device ceased, followed by the salivation linked with the second, and, finally, the topmost device, the investigator as much as saw the inhibition spreading farther and farther through the centres of the brain.

There was another point of interest. When the investigator once more applied the topmost device two minutes later, the saliva flowed again. The conditioned reflex re-appeared. This meant that after a certain time the inhibition retreated, as it were, abandoning the temporarily occupied brain cells.

A bit later the same thing happened with the second device. Applied again, it also provoked a flow of saliva. The conditioned reflex reappeared. The region affected by inhibition had shrunk still more.

But the device nearest to the paw would not bring on salivation, however often it was applied. In its case the inhibition was complete. It was concentrated at that site.

It could be said, therefore, that inhibition processes are attended by a process of spreading, or irradiation, which is then followed by a process of concentration.

Further studies of excitation and inhibition disclosed another remarkable fact: the two processes influenced each other. The excitation of nerve cells in one area of the brain gave rise to inhibition in other areas. Similarly, inhibition processes were attended by excitation in neighbouring areas. It was as if processes of one kind, originating at some definite point, induced processes of the opposite type in the near-by areas of the brain, processes known as induction.

Pavlov's stubborn investigations of the various phenomena bound up with conditioned reflexes, brought him, step by step, to the discovery of the principal regularities of the higher nervous activity.

THE CORTEX

One of his experiments consisted of three series of tests. In the first series several conditioned reflexes were evolved in a dog: an acoustic reflex to the sound of a bell, a visual reflex to a winking electric lamp, etc. Each conditioned excitation brought on salivation.

The second series of tests opened with an operation: the dog's cranium was opened and its cerebral cortex removed. When the dog had recovered from the operation, the investigators tried to activate the previously formed conditioned reflexes. But the reflexes were gone.

In the third series of tests the investigators worked patiently to form anew the previous reflexes, but failed to produce a single one. When the dog was taking food, saliva flowed freely. The dog's unconditioned reflex was intact; it had survived the operation. But all efforts to form conditioned reflexes by associating some signal with the feeding—the sound of a bell, demonstration of food from afar, or preparations for feeding—failed utterly.

Deprived of the cerebral cortex, the dog lost its faculty of forming conditioned reflexes. This proved that the cortex played the main role in forming conditioned reflexes—a cardinal point in the Pavlovian teaching.

ANALYSORS

AMONG THE EXPERIMENTS involving the removal of the cerebral cortex one evoked particularly great interest. Only some sections of the cortex were removed in this experiment, and it developed that some of the conditioned reflexes remained intact, while others vanished tracelessly. The ringing of a bell, for instance, which previously brought on a liberal flow of saliva and caused the animal to turn its head and prick up its ears, made no impression on it. But signals of another kind, the light signal, for instance, yielded the usual results. They remained excitors of the conditioned food reflex. Saliva appeared, just as though there had been no operation.

In the first case we may assume that the sound signal failed to stand out among all the other external stimulants reaching the outer apparatus of the acoustic organ. It was as though the cortex failed to receive them. Clearly, the specialized part of the cortex distinguishing sound stimulants and able to single out, or analyze the signals reaching it from the outer world, had been removed during the operation. That is why the conditioned reflex did not form. Pavlov built upon experiments involving the removal of part of the cerebral cortex to elaborate his teaching on analysors. Under analysors Pavlov implied the peripheral apparatus of the sense organs, the neural communication lines conveying nervous impulses to the central nervous system, and those cells of the cortex that receive them and convert them into sensations. They form a single whole, a single organ that analyzes excitations transmitted from the outside world. Pavlov defined analysors as "apparatuses which break up the outer world into elements and then transform excitations into sensations."

The cortex is something of an aggregate of all the analysors. It breaks up the outside influences on the organism into separate signals. That is how it differentiates, or, as Pavlov puts it, fractionizes, the world of phenomena. And the higher the animal, the finer and more accurate the fractionization. The world breaks up into colours, smells, sounds, and contacts with all their minute shades and features, allowing living beings to distinguish the objects and phenomena of their environment.

The study of analysors yielded some curious facts. It turned out, for instance, that one group of analysors may be more developed than others. Thus, bloodhounds distinguish up to half a million different smells. At the same time they are scarcely able to distinguish colours. They do not distinguish red from green and yellow, for instance, and see everything about them in black and white hues. Man, we might say, sees the world as he would a coloured film, while the dog sees it as an ordinary black-and-white show. Scientists have an explanation for the limited range of colours distinguished by dogs. It all goes back to their historical development in the animal world. Dogs descend from wolves. Their forefathers led a nocturnal life, and their eyesight developed no more than was necessary to see at night, when there is a scarcity of colours.

REFLEX AND BEHAVIOUR

THE MAN SITTING AT THE TABLE put his hand on a metal plate. Electric current was then passed through the plate, and he instantly jerked back his hand. It was a reflex action on his part. But there was one more thing to the procedure. A bell was rung for five seconds before the current was switched on.

This was repeated several times, and each time the hand jerked back under impact of electric shock. Suddenly the man turned pale. The attendant who had been switching on bell and current approached him, and said quietly:

"Your hearing is perfect. Stop faking."

The man had insisted that he was deaf, and underwent an examination. Each time he jerked back his hand under the impact of electric shock it was an unconditioned, inborn reflex action. The sound of the bell formed an attendant conditioned reflex. When the bell rang the last time, however, the current was not switched on, while he jerked back his hand exactly after five seconds. That was an act prompted by his newly-acquired conditioned reflex, a reaction to conditioned sound excitation. In other words, the man was not in the least deaf, or the conditioned sound reflex could not have been evolved.

In this manner conditioned reflexes help to detect people simulating deafness.

The worker leaves his house in good time. He is sure he will not come late to work. But on hearing the factory whistle, which sounds some time before the beginning of his shift, he unwittingly quickens his steps. That is a conditioned reflex evolved in him by the factory whistle.

Cross a railway track and walk some distance away from it. The roar of an approaching train and the shrill whistle of the locomotive make you start, nonetheless, and you run a few quick steps, although you are out of danger. That is also a conditioned reflex evolved by the repeated sight of speeding trains, whose roar and whistle has made you wary.

Children who frisk about before bedtime take long to fall asleep. It is the excitement that has spread through the cerebral cortex, the irradiation of excitement, that is at play here as well.

Towards the close of a dull lesson schoolchildren become fidgety and noisy. That is the result of inhibited attention, brought on by the monotony of the lesson. The inhibition in one group of brain centres induces excitement in other centres.

The general conclusion is now plain. Psychic behaviour, it develops, can be explained physiologically. Any outward factor can give rise to a conditioned reflex, provided it is bound up for some time with some unconditioned reflex—the food reflex, for example, or the reflex of defence and orientation. The outer world is an excitor of a vast number of conditioned reflexes. Some of them fade, some are in the stage of conception, others are developing and gaining strength, while others still are being inhibited and are on the verge of vanishing. All of them taken as one determine the behaviour of living beings, particularly highly-developed beings. All the phenomena of the outer world react upon the sense organs and, consequently, upon cortical centres, materializing into actions.

Such is the nature of conditioned reflexes, or temporary associations between a body and its environment. Had there been no reflexes of this kind the existence of animals and men would have been hazardous, unstable, and unadapted to the surroundings.

A NEW SPHERE

In the course of several decades Pavlov and his associates studied the functions of the central nervous system in thousands of brilliant experiments. They determined how conditioned reflexes evolve in higher animals, learnt how these reflexes fade, how they are inhibited, and increased. They discovered the concentration of excitation in specialized, restricted areas, and the differentiation, or distribution of excitation at definite points of the cortex. They established the part sleep plays in the general inhibition of conditioned reflexes, relaxing the nerve cells and protecting them from excessive excitation and attendant exhaustion.

Pavlovian research gradually disclosed a long line of physiological regularities in the work of the brain. Many things became tangible in the behaviour of animals and men. By changing the order of excitation in conditioned reflexes and reversing the usual sequence of excitation and inhibition in the cerebral cortex, investigators learned to change the course of neuro-psychic processes and to make them pathological. They substituted reactions of inhibition for reactions of excitation, and vice versa, juggled the reactions, and cut into one reaction with another, creating neurotic animals with all the symptoms of nervous diseases very much like similar diseases in human beings. Common occurrences in man and animal gave reason to hope that a number of the measures they evolved could be utilized in treating neuro-psychic disorders in human beings suffering from mental diseases. Pavlov's laboratory work was continued at clinics. The reversal of conditioned reflexes and the inhibitory effect of prolonged sleep were turned to medical use.

All these highly interesting facts speak of the major efforts of the group of scientists guided by the remarkable genius of Pavlov. They disclosed the influence of the outer world on the cortex of the cerebral hemispheres. The findings of the Pavlovian school were invaluable. But all the successes, however significant, solved only part of the problem. Physiologists found the laws governing reactions of the cortex to excitation transmitted by the sense organs from the outer world. But there is also the inner world, the world of internal organs—a domain of most complicated and delicate processes in tissues and cells. Yet all the 19th century and early 20th century physiologists ignored the connection between that domain and the cerebral cortex. Organs and tissues, meanwhile, play a primary part in the life of an organism. The scientists ignored it simply because they failed to see it. They thought the liver, kidneys, spleen, metabolism and internal respiration, and heat regulation—that all these and other organs and phenomena, had nothing to do with the cortex, and were independently governed by the vegetative nervous system.

FIRST SURPRISE

INTERNAL ORGANS ARE NOT ALL like the salivary gland, whose secretory function is easily observed at any time. It is far more difficult to study the secretion of bile by the liver, or the thyroid gland hormone. No investigator ever suspected that it was possible artificially to regulate such deeply seated organs.

That, in all likelihood, precluded all attempts on the part of scientists to question the existing view on the autonomous function of the vegetative nervous system.

But Bykov, one of Pavlov's most prominent pupils, found a key to the problem. A new, revealing chain of scientific discoveries began with a modest and presumably accidental event.

Another of Pavlov's associates was investigating micturition. The problem was comparatively simple. It all came down to administering water to the experimental animal and watching the excretion of urine from the kidneys. This, in effect, was simple, but required great surgical skill. The dog's bladder had to be removed, and the ends of the ureters leading from the kidneys to the bladder drawn out and attached to the skin.

These ducts poured the urine from the kidneys into measuring cylinders. The cylinders were graduated, facilitating a study of the excretory function of the kidneys.

The dog was kept in a special stand. Water was introduced directly into its rectum. The amount of urine naturally increased. The water, absorbed by the blood through the mucous membrane of the rectum, made its way through the body, and, excreted by the kidneys, reached the cylinders through the ureters drop by drop.

After the fourth or fifth time the conditions of the experiment were changed. The water was introduced into the rectum as before, but it was then immediately drained. Under the circumstances it was hardly to be expected that urination from the kidney would increase, since the water was drained before the blood could absorb and convey it to the kidneys. But the investigators saw to their great surprise that the level of urine in the glass vessels rose nonetheless.

The experiment was repeated several times over. It was also performed on other dogs. The results were all the same: after a few administrations of water the mere contact of the rubber tube and water with the walls of the rectum, increased the micturition, although the water was instantly drained and had not been absorbed by the blood.

Then came a new change. The dog underwent a similar procedure. Water was introduced into its rectum as usual, and then instantly drained. Yet the quantity of urine from the kidney failed to increase. This occurred for the simple reason that the experiment, quite the same in all other respects, were altered in a single detail: the dog was transferred to another room. In new surroundings the experiment yielded a new result.

The entire experiment was then repeated from beginning to end. Water was again introduced into the dog's rectum and allowed to remain there. The level of fluid in the graduated glass vessels rose steeply. Then water was introduced and instantly drained. There was no water in the rectum, yet urination increased, as it had in the other room.

It was all clear now. The increase in the quantity of urine after water was introduced to the rectum was an unconditioned reflex. The contact of rectum and rubber tube, which was associated with the unconditioned reflex, had become the starting point of a conditioned reflex. The rubber tube took the place of the bell in the conditioned salivation reflex. The dog's removal to a new room, which altered the conditions of the experiment, inhibited the conditioned reflex, but when the unconditioned reflex was again brought into play to back it up, the inhibition was eliminated.

AN AXIOM FALLS

An animal organism, endowed as it is with a capacity for evolving conditioned reflexes, may enter into various relations with its environment only if it is able to note everything that is going on about it. Conditioned reflexes help living beings to adapt themselves to each change in their environment.

This creates the need for a mechanism that would receive all external influences. Animals and men have such a mechanism—the sense organs and the nervous system. The peripheral endings of the sense organs, which receive external irritations, have come to be known as receptors. Nerve fibres leading from the receptors transmit irritations to the central nervous system, while other fibres lead from the central nervous system to organs that actuate the desired reaction. These organs, whatever they may be—glands, muscles, or blood vessels—are known as effectors.

The kidneys, like the salivary gland in Pavlov's experiment, were effectors in the experiments on urination performed by Bykov and his associate, Alexeyev-Berkman.

Yet we know that conditioned reflexes are formed through a tie-up between receptor and effector. To form a conditioned reflex the association of receptor and effector necessarily occurs in the cerebral cortex, and nowhere else. But the kidneys are internal organs, and as such should be governed by the autonomic, or vegetative nervous system. That, at least, was the axiom prevalent in physiology. How then, could the cortex, whose part in the formation of a conditioned reflex is indispensable, react on the kidneys if it is unconnected with them?

This question loomed as a seemingly insuperable obstacle. But to science an obstacle is the starting point of a new problem clamouring for solution. In his quest for it Bykov made use of Pavlov's method of conditioned reflexes evolved on the basis of external excitation. The investigator had to perform an experiment that would involve both the internal, and the sense organs—eyesight, and hearing, which are associated with the outer world on the one hand, and with the cerebral centres on the other.

The dog with the exposed ureters became the subject of a new experiment. Water was again introduced into its rectum. But it was preceded by an electric light signal. First light, then water. This combination was repeated several times. As expected, urination increased, since the water was absorbed by blood.

Then the light alone was switched on, and water was withheld. All doubts cleared: the kidneys responded to the light with intensified urination. A visual impulse and a visual receptor had made the kidneys work.

But an exacting investigator always checks his findings. This time the ear replaced the visual organ. Water was poured into the dog's rectum to the regular strokes of the metronome. The combination had due effect: the quantity of urine grew.

And then again, just as in the case of the preceding experiment, water was withheld. There was the sound of the metronome, and no water. Nonetheless the graduated test tubes attached to the ureters began to fill with urine.

This time an auditory, or acoustic impulse, and an acoustic receptor, made the kidneys work. And both visual and auditory impulses have but one path, a path leading to centres located in the cerebral cortex. That is the only place where visual and acoustic impulses could excite the cells of their respective cortical zones, whose impulses, in their turn, were transmitted to nerves of the kidney, and roused the effector to action, increasing its urinary function.

This proved beyond any doubt that the brain cortex had a hand in the work of the internal organs. The contention that the vegetative nervous system was autonomous, was exploded.

EXPANDING LIMITS

THE INVESTIGATOR COULD at will influence the function of the kidneys. This discovery was an important event in physiology, an event that merits a place in the history of science.

The century-old notion that the organism comprised two separate spheres—the sphere of vegetative processes, and the sphere of voluntary motor functions—was bankrupt. Bykov's experiments showed that consciousness has direct bearing on the realm that was previously thought to be totally independent. This was a crushing blow to the old-time conception that only skeletal muscles were subject to consciousness and will, and that brain centres had no sway over internal organs and physiological processes.

But Bykov's experiments with the kidneys were only the first step. The kidneys, after all, could be an exception. The tests had to go on. Bykov and his associate, Rikkel, next studied the liver.

The liver is a large and heavy organ which plays an exceptionally big role in the body. It performs several functions. The simple experiment performed by Ekk, a Russian scientist, showed how important these functions are. His interesting operation involved the liver and its accessory blood vessels.

The blood vessels leading from the intestines gradually converge and form the portal vein. This vein enters the liver and there breaks up into a great many minor vessels. It brings to the liver all the blood from the intestines, with all its absorbed substances and products of digestion.

The blood leaves the liver by the hepatic vein, which opens into the lower vena cava. Both are part of the systemic, or general blood circulation.

If the portal vein were connected with the lower vena cava before it entered the liver, such a link between them would form a detour. The portal vein would then have to be ligated at its point of entry into the liver, and all the blood coming from the intestines would by-pass the liver, reach the lower vena cava directly via the detour, and join the general blood stream.

Such an artificial link between the portal vein and the vena cava is known as Ekk's operation. Improved and adapted by Pavlov, it is now called the Ekk-Pavlov operation.

Dogs that underwent this operation died within a few days. Nothing could save them. But the operation was not directly to blame for their death. From the surgical point of view the operation was successful. The death was due to poisoning. The dogs were killed by the products of protein decomposition and by other poisonous substances, such, for instance, as indole, scatol and phenol, which are produced in the intestines by bacteria, and penetrate into the blood.

Should the blood have taken its normal course through the liver, and not via the artifical detour, the liver would have rendered the poisons harmless. It would have protected the organism from their effect.

Another function of the liver is to convert carbohydrates into glycogen, which is so essential to the muscles. What is more, the liver secretes bile. This greenish fluid gathers in the gall-bladder, and enters the duodenum in required doses. Its part in digestion is highly important. Fats, for instance, are almost indigestible without bile. Lipase, the ferment which splits fats, is active only in the presence of bile. The bile turns fats into an emulsion, i. e., a dispersed substance held in suspension, which facilitates their splitting. In the absence of bile the absorption of fats is impeded, and a person may consume great quantities of nourishment and yet remain emaciated by virtue of fat deficiency. The bile promotes the movements, or peristalsis of the intestines, which precludes stagnation of foods. It reinforces the pancreatic secretion of ferments indispensable to digestion, such as trypsin, which act on the protein, amylase, maltase, and lactase. The latter convert starch into various carbohydrates.

In the absence of bile all these processes are deranged.

Liver functions are invisible, and take place independently of our consciousness and will. No one ever had an inkling that the higher nervous centres could impede or accelerate its complex mechanism. It was up to Bykov and Rikkel to see if that was so.

First they had to open an approach to the bile and find a way of watching how it was secreted. Access to the bile duct was achieved surgically through the abdominal wall. The investigators could now gather the bile in a test tube.

Next they had to find an agent which would provoke the secretion of bile; in other words, they had to be able to induce the unconditioned liver reflex.

The investigators possessed such an agent in hydrochloric acid and diluted glycocholate of sodium. An injection of either induced an immediate increase in bile secretion. Bile itself, even in a diluted state, also produced a similar effect.

The dog was put into a special stand, and was instantly injected sodium glycocholate. The investigators had previously ascertained how much bile normally gathered in the test tube in, say, two hours, and watched it rise steeply under the cholagogue effect of the sodium glycocholate.

The dog was put into the stand and injected three days running.

Each time there was an increase in bile secretion. On the fourth day the animal was also put in the stand, but nothing further was done. The glycocholate of sodium, the unconditioned irritant, was withheld.

Yet the result was the same: the quantity of bile increased. The conditioned reflex worked.

Where did the dog get it? In its case there had been no electric light, and no metronome. It was the stand. The cholagogue injection was each time associated with the stand, and this combination had formed a conditioned reflex. A temporary association had evolved between the stand and the intensified function of the liver. And this, as we know, could have occurred only with the help of the cortex.

Another check was made. A cat was brought in when the dog was in the stand and bile was pouring liberally into the glass vessel. Its flow ceased instantly on sight of the cat. Inhibition set in.

The dog's reaction to the appearance of the cat was either fright or anger. That meant that fright or anger, which are psychic acts, inhibited the function of the liver.

Consequently, the liver, like the kidneys, is under the influence of the cerebral cortex.

DISPLACED SPLEEN

THE INVESTIGATORS would not stop there. They carried on.

The spleen is a curious organ. Above all, it has a close connection with blood circulation. It is a storehouse, as it were, which holds a reserve of millions of erythrocytes. At times of need they can be poured in great masses into the general blood stream. Exhausted erythrocytes, which have lost their viability, disintegrate in the spleen. Their constituents, chiefly hemoglobin, are used on the spot in the form of iron to produce new hemoglobin. The spleen thus contains more iron than any other organ.

The spleen also has certain protective functions, safeguarding the organism against pathogenic microbes. It has considerable areas of reticulo-endothelial tissue, which mobilizes its cells against microbes and infection. In a victim of, say, typhoid or malaria, the spleen is hard and dilated. When in this condition, it is easily palpable below the left costal margin. This, to a certain extent, is visual proof of its part in the defence of the organism. On the victim's recovery the spleen contracts and withdraws to the abdominal cavity. It is then no longer palpable.

The spleen is the only internal organ which greatly changes in size in a normal state, either expanding, or contracting under the effect of various processes in the body. The only processes that it ignored, it was thought, were those in the higher nervous centres. The spleen, it was thought, was independent of the cortex to an even greater degree than the kidneys and liver.

Naturally enough, the spleen arrested Bykov's attention. The problem did not appear particularly difficult, considering what had already been done in this sphere. But there was one point of difference between the planned investigations and the preceding experiments. This difference made things complicated.

The spleen does not secrete anything that could be gathered and measured. Neither has it a fluid similar to urine or bile, nor a duct that could be brought to the surface, or that could be tapped with the help of a fistula.

Since these tried methods of research were useless in its case, new methods had to be found. The spleen had to be made accessible to observers. It was a difficult thing to do, but it had to be done. And the investigators did it.

The spleen is situated in the upper left part of the abdominal cavity between the intestines, the kidney, and the diaphragm. The investigators moved the spleen from its usual place to a spot more suitable for observation. They lifted it surgically from the depth of the infracostal region and placed it close under the skin. It became palpable and its oval surface bulged visibly under the skin.

The operation was a success. The animal remained fit. Its condition was perfectly normal. For the first time in the history of physiology, scientists were able to study the spleen under normal living conditions.

The most striking feature of the spleen, as we have said, is its changing size. It was this particular feature that served Bykov and Kelman, his associate, as a key to the whole problem.

Adrenalin is a substance secreted by the adrenal, or suprarenal capsules. It may be regarded as a stimulant of vital activity, and appears in the blood during fits of anger, or excitement; it accelerates the rhythm of the heart and increases the amplitude of its contractions. It also generates muscular energy, and stimulates action. In acts of defence or attack the secretion of adrenalin increases, and it affects the spleen, making it contract. And that is quite natural, because at such times the body consumes excess quantities of nourishment. In contracting, the spleen ejects its reserves of blood into the general stream, and supplies extra nourishment.

Physiological laboratories have an apparatus called the oncograph. It records changes in the volume of organs by means of a curve. It helped to study the spleen's unconditioned reflex to adrenalin by recording its contractions. They could be felt, seen, and registered. The problem of directly observing the spleen was solved.

It now remained to evolve the conditioned reflex. A metronome was used for that purpose. Its strokes—of which there were 60 to a minute—were geared to the adrenalin injection. The metronome was turned on three minutes before the injection, and turned off three minutes after it.

Seven injections were made, and seven times the spleen contracted three minutes after the injection.

The eighth time there was only the sound of the metronome—three minutes, and then another three—and again at the beginning of the fourth the spleen contracted, just as though it had received an injection of adrenalin.

But there had been no adrenalin injection. The contraction was brought on by the strokes of the metronome—a direct result of the conditioned reflex.

The investigators also evolved a conditioned reflex to a whistle. The dog was pricked with a pin in its hind leg. The spleen responded to the pain by contracting. This was an unconditioned reaction of defence. A whistle was sounded each time before the pinprick. This was repeated ten times. And the eleventh time there was only the whistle, and no pinprick. Yet the oncometric curve leapt upwards, showing a contraction of the spleen.

The conditioned reflex had produced the desired result. The metronome and the whistle, both of them acoustic phenomena of the outer world, affected an internal organ through the cerebral cortex.

There was one more striking detail. Adjusted to 120 strokes per minute the metronome had no effect on the spleen. Sixty strokes per minute acted as a conditioned excitor, while 120 strokes induced inhibition.

The differentiation of 120 from 60 strokes, of frequent from slow strokes, was also unquestionably an act of the higher brain centres.

WORK AND OXYGEN

THE FINDINGS AT BYKOV'S laboratory showed that the investigators were on the right track. Numerous experiments on vitally important organs yielded one and the same result.

But those were all separate organs. Yet there are processes in the organism which involve entire systems of organs, processes that are a result of the activity of the body as a whole, processes linked with the functions of numerous tissues.

Internal respiration, or gaseous diffusion and interchange, chiefly consisting of the consumption of oxygen and elimination of carbon dioxide, belongs to this group of processes.

The first few seconds after its birth a child is still connected with its mother's body by the umbilical cord, which carries blood vessels—an artery with oxygen and a vein with carbon dioxide. The moment the cord is cut, the supply of oxygen to the child's organism ceases. The carbon dioxide has no exit. The accumulation of carbon dioxide irritates the child's respiratory centre, provoking the first movement of the thoracic respiratory muscles. A sigh follows, the first sigh of a newborn. Oxygen is drawn into the lungs with this sigh, and the life of one more human being, begins.

Carbon dioxide is an excitor of the unconditioned respiratory reflex. This reflex does not depend upon will and consciousness. Man may arrest the movement of the muscles producing respiration, but respiration itself is entirely automatic. No one ever thought it would be possible to increase at will the consumption of oxygen by the cells, and the elimination of carbon dioxide from the tissues of the body.

At Bykov's laboratory his associate, Olnyanskaya, checked whether or not internal respiration was dependent upon the higher nervous activity. All efforts, all the energy expended by a body are determined in physiology by the quantity of consumed oxygen. At times of work this consumption doubles and trebles. We know all that. The greater the man's physical exertion, the more intense and deep is his breathing; in this manner the body receives more oxygen.

But here was a strange fact. Men sat idly, and yet their oxygen consumption rose steeply, and their internal respiration intensified. They were by no means sick people in whom the normal processes of absorption and elimination of gases may have become deranged. They were perfectly healthy factory workers who were being studied by Academician Bykov's associates. They were not in their factory shop, but in a room on the floor above it, which was temporarily turned into a laboratory. But their oxygen consumption was as high as it would have been if they had been hard at work, controlling levers, handling heavy parts, forging or stamping.

You have probably guessed what it was all about. At this hour the men were usually at their work-benches. Quietly seated in the laboratory, they heard the factory whistle. What is more, the laboratory itself, situated a floor above the shop, was filled with the noise of machines, the rumble of cars, and the voices of foremen and workers.

All these sounds acted as a conditioned excitor on the factory workers. It was this that raised their consumption of oxygen and elimination of carbon dioxide.

The experiment, repeated on a Sunday, yielded quite opposite results. Internal respiration did not intensify. The men were the same, and the laboratory was the same, and so was the investigator. There was only one difference—it was a holiday. And this was enough to inhibit the conditioned reflex. Yet the faculty of distinguishing a working day from a holiday belongs to the sphere of psychic functions. Clearly, the cortex intervened in the processes of internal respiration in both cases, intensifying them in the first, and arresting them, in the second.

All this was quite convincing. There was no doubt any longer that processes taking place in tissues were subject to the same laws that governed the kidneys, liver, and spleen.

But the investigators would not rest content. A fact was indisputable only if it could be reproduced in an experiment. The dogs brought to Olnyanskaya's laboratory faced a drawn-out preparatory period.

Their internal respiration had to be investigated in a state of complete rest and in the absence of any muscular movements. This meant that they would have to lie still in the course of several hours, and, moreover, wear a special respiratory device that would communicate by means of tubes with a gasometer. This was extremely trying for the dogs.

Yet the investigators' patience won out. Six months later they could launch their experiment, for the dogs had learned to lie still.

Tyroxin is the hormone of the thyroid gland. Introduced into the body it steps up internal respiration. Its effect lasts up to six days.

A dog had five hypodermic tyroxin injections. Internal respiration jumped markedly; the consumption of oxygen increased, and so did the elimination of carbon dioxide. This was most pronounced on the second and third days after the injections. Then internal respiration gradually subsided, and returned to normal.

But no injection was made the sixth time. Yet the gasometer readings showed a rise in internal respiration. The investigators showed no surprise. Their electric bulb had done its job. Two minutes before the tyroxin injection an electric light had dispersed the dusk of the darkened room on each of the first five occasions. This conditioned excitor was associated with the unconditioned reflex, and on the sixth occasion it acted on its own.

This plainly showed the part played by the cerebral cortex in processes of internal respiration. At the same time the experiment brought the investigators face to face with another major problem.

In these tests internal respiration was stimulated by tyroxin injections. Under ordinary circumstances, however, there is no need to inject tyroxin, for it is supplied to the organism in required quantities by the thyroid gland. That is clear enough. But what happens when internal respiration is stimulated by a conditioned reflex? Tyroxin is not artificially introduced. Does the thyroid gland produce more of the hormone? Or is some other factor brought into play, some special, as yet unknown mechanism that promotes absorption of oxygen and elimination of carbon dioxide? That could also be.

That was the question, and it could not remain unanswered.

New investigations were launched at Bykov's laboratory. They were delicate, complicated, and extremely interesting.

DUAL CONTROL

THERE WAS NO DOUBT whatsoever that in the case of the first experiment the light of an electric bulb set off the mechanism that stimulated internal respiration. The light had acted on the receptors, on the sense organs receiving visual excitation. It reached the cerebral cortex and stimulated the respective nervous centres. The latter transmitted impulses to the physiological apparatus inducing increased internal respiration. The investigators wanted to locate this apparatus, to see if it was really the thyroid gland.

Impulses from the cortex are transmitted along nerve fibres. The thyroid gland must lose its nerve connections with the brain. The nerve fibres must be cut. The impulses will then fail to reach the thyroid gland, and, presuming it really is the mechanism in question, internal respiration will not increase.

The notion was perfectly logical. It was no doubt a key to the problem, and would prove beyond question that the thyroid gland influenced internal respiration.

Olnyanskaya performed the required operation. She reached the dog's gland and severed all the nerves leading from it to the brain. She excluded the thyroid from the nervous system.

After the animal recovered from the operation the old experiment was repeated. Tyroxin injections were accompanied by a flash of light in a darkened room. Everything was done to form a conditioned reflex. Then came the flash of light unsupported by a tyroxin injection. It was thought that the conditioned reflex would not be actuated this time. The influence of the thyroid had, after all, been eliminated.

But everything happened just as though the thyroid had not been isolated from the nervous system. Internal respiration increased as usual, reaching its highest point on the third day, and then waning gradually.

It was naturally assumed that there were some other channels that had escaped notice, by which the cortex influenced the thyroid. The thyroid had been deprived of its nervous connections with the cortex, but these other channels had remained. It was they that had made the thyroid act. What to do? How to eliminate all possible participation of the thyroid in internal respiration?

The way out was finally found. The thyroid was to be totally excised. It would then be clear what part it played in internal respiration, and whether some other stimulants existed.

Olnyanskaya removed the thyroid. And this, it turned out, yielded an accurate and convincing reply. A hypodermic tyroxin injection could still raise internal respiration, but the flash of light, or any other conditioned reflexes, could not.

It was now indisputable that the thyroid was the principal factor in internal respiration. Without its hormone internal respiration could not increase, provided tyroxin was not introduced into the body artificially.

All this was incontestable. Yet there was a missing link. It had to do with the sundering of the thyroid's nerves, with what physiologists call the denervation of the thyroid.

Prior to its removal the denervated thyroid had responded to the conditioned reflex, to the flash of the electric bulb. The nerves had been cut, yet impulses from the cortex had not failed to reach the gland. Naturally, Olnyanskaya went to considerable trouble to get to the bottom of it.

The cortex transmitted impulses to the thyroid. After the nervous connections had been cut, the cortex had unquestionably found some other channel to convey its message. It was this supplementary channel that Olnyanskaya wanted to locate.

After many unsuccessful attempts she finally turned her attention to the hypophysis, a pituitary body at the base of the brain, which is also a gland of internal secretion. Its hormone has a bearing on the body's growth and on fat metabolism. When its functions are deranged it either impedes growth, or, conversely, causes its excess. Almost all dwarfs and giants have the deficiency or excess of its function to blame for their malformation. In people with an abnormally functioning hypophysis parts of the body—arms, legs, or the jaw—may be enlarged out of all proportion. This condition is known as acromegalia. In other cases it brings on excess obesity.

Olnyanskaya was aware of a connection between the thyroid and the hypophysis. Sometimes thyroid disorders were also a cause of dwarfism. True, such dwarfs were different from pituitary dwarfs. Yet the thyroid and the hypophysis both influenced growth and development. Furthermore, there was reason to believe that injuries to the thyroid give rise to a greater activity of the hypophysis. In short, these two organs were doubtlessly connected with each other. It was, therefore, natural that Olnyanskaya looked in the hypophysis for the key to the function of the denervated thyroid.

A new subject was brought to the laboratory, a perfectly healthy dog with an undamaged thyroid gland and a normal hypophysis. Tyroxin injections and light signals were applied to evolve the conditioned reflex of internal respiration. After that the dog's hypophysis was excised.

The conditioned reflex did not vanish. Each time the electric bulb was switched on at the usual hour, the gasometer indicated a rise in oxygen consumption.

Then the investigator denervated the dog's thyroid. The conditioned reflex disappeared. It ceased to influence oxygen consumption and carbon dioxide elimination. The riddle was solved. To isolate the thyroid from impulses transmitted by conditioned excitors it was necessary to denervate it, and remove the hypophysis.

This meant that impulses from the cerebral cortex reached the thyroid by two routes. One was direct, by the nerves, and the other, via the hypophysis. When the first was cut the cortical impulses to the hypophysis raised its hormonal function. A greater quantity of hypophysis hormones poured into the blood, reached the denervated thyroid, and stimulated its function, resulting in a greater output of tyroxin. This is known as the humoral connection of organs of internal secretion through the fluids of the body, through the blood and lymph.

Everything was perfectly clear. The cerebral cortex has two ways of influencing the function of internal organs. One is the principal way, via the nerves, and the other—a supplementary, or humoral way.

RETURN HOME

IT WAS AN ORDINARY GOODS train, the kind we see in great numbers on any railway. Its conductors were just like the conductors of any other goods train. They were men of ordinary build, and their health was perfectly normal.

But when Bykov's associates—Slonim and Ponugayeva—investigated them they discovered a great many interesting things.

Thermoregulation is the maintenance by a body of its constant normal temperature, irrespective of external temperature fluctuations. This is an important faculty. In its absence the life of an organism would have been impossible. Somewhere in the south a body temperature equalling an air temperature of, say, 122°F would cause immediate death, for the protein in the body is known to curdle at a temperature approaching 126°F. Conversely, in winter a man would turn into a block of ice at a mere 15°F.

The human body has a very sensitive heat regulation system, which involves the heart with its blood vessels, the vegetative nervous system, and the glands of internal secretion. The centre of heat regulation is situated in the hypothalamus, or between-brain. Heat regulation helps the body to adapt itself to the outer temperature. It maintains its inherent temperature within the limits of heat regulation in any cold, or heat. It is always about 98.5°F.

When it is hot man perspires. The perspiration evaporates. To turn into steam, it requires heat. Consequently, the body's loss of heat increases, and body temperature drops. At the same time the cells of the body produce less heat. This means that their activity slows down, causing an attendant slow-down in internal respiration. As a result, the temperature of the body cannot rise. In the cold the tissues and cells generate more heat, expending greater energy. The internal respiration increases. As a result, the body temperature cannot drop. That, in brief, is the essence of thermoregulation.

But let us return to the goods train. At 22°F below zero it should be just as cold in Leningrad and Lyuban. A person clad in the same clothes should feel the cold as acutely in Lyuban as he does in Leningrad. That is self-evident. But goods train conductors travelling between Leningrad and Lyuban in open platforms disagree. They say it is warmer travelling towards Lyuban, though the cold there may be greater than in Leningrad. They even unbutton the collars of their sheepskin coats. They are always more aware of the cold, they say, on their return trip.

Investigators recorded that the conductors' internal respiration was greater on their way to Lyuban. Their cells, therefore, generated more heat. That is why they felt warm enough to unbutton their collars. Meanwhile, on the way back to Leningrad their internal respiration dropped, their bodies generated less heat and body temperature fell, causing them to freeze.

It is easy to explain the whole affair after the studies of Bykov and his associates. As the train departs from Leningrad the men face a long trip. As though aware of it, their thermoregulating centre prepares for a prolonged cooling of the body. It sends out signals, as it were, for greater heat generation.

The trip to Leningrad, meanwhile, is a trip homewards. At home the men get warmth in plenty. The thermoregulating centre, as though informed of this, lowers the generation of heat. The consequent heat shortage makes the body more sensitive to cold.

Only the cerebral cortex, the brain itself, can inform the thermoregulating centre, as it were, that the men are nearing Leningrad, or vice versa. The whole phenomenon may be explained by the action of conditioned excitors—the approach to Leningrad, and vice versa—and conditioned thermal reflexes.

It turns out that thermoregulation with its deep-seated, concealed processes, is also under cortical control.

INTESTINAL LOOP

BYKOV'S INVESTIGATIONS took place in laboratories under specific conditions. The subjects of his experiments were animals—mainly dogs.

But one day he learned of a case involving the victim of a tram accident. The man had suffered extensive injuries of the abdomen. The wound had healed improperly, and an opening remained between its edges. Whenever the nurses took off the bandage one loop of the small intestine protruded from it. Bykov availed himself of this opportunity to make observations.

The small intestine makes worm-like peristaltic motions which force the food onwards along its lumen. The motions are produced by peculiar hollow intestinal muscular structures and a special nerve apparatus.

Bykov visited the patient shortly before dinner. The scientist examined the unbandaged wound and protruding loop. He spoke deliberately of the forthcoming dinner, and as he spoke the intestinal loop visibly reacted to his words. It moved vigorously at times, relaxed at others, and then moved again.

Its wave-like motions were stimulated by the mention of tasty dishes, and subsided whenever mention was made of unappetizing things. A conditioned excitor induced the intestinal loop to behave as though food had really entered the intestines.

But Bykov had done nothing to evolve a conditioned excitor. He had not associated any visual, acoustic or tactile excitors with the act of feeding. He had merely chatted with the patient. That was all. Here we come to an extremely interesting fact: the existence of a special system of conditioned reflexes.

EXPERIMENTS WITH GLUCOSE

Before going any further let us view an experiment which confirms the participation of consciousness in the activity of the intestines. It was a most delicate experiment with a dog, which revealed the innermost properties of the intestinal walls.

The dog's intestinal loop was skilfully drawn out to the surface, and a fistula was made in it, giving access to its interior. No nerve fibres, arteries, or veins of the intestine were damaged, and its physiological processes remained absolutely normal, just as though it had not been removed from its usual place in the abdominal cavity.

A large quantity of glucose was then poured into the loop through the fistula. Glucose passes readily through intestinal walls, and most of it was soon absorbed by the blood.

A special preparation called saponin increases the penetrability of the intestinal walls. When this compound was added to an identical quantity of glucose in a subsequent test, the latter was absorbed without a remainder within the same space of time. That was the effect of an unconditioned reflex to saponin.

The strokes of a metronome were associated with the administration of saponin. An auditory conditioned reflex was thus evolved on the basis of the unconditioned one. That took quite some time. Finally, the glucose was poured into the exposed intestine. The metronome sounded its regular strokes. But the saponin solution was not added.

In spite of that all the glucose, all of it without a remainder, passed through the intestinal wall into the blood.

That was a stunning occurrence. The penetrability of the intestinal wall, that most complicated, delicate, and intimate mechanism of mucous membrane cells, obeyed the strokes of a metronome, an acoustic excitor.

SECOND SIGNAL SYSTEM

LET US NOW RETURN to the patient with the protruding intestinal loop. In his case words had acted as excitors of a conditioned reflex.

Words are excitors of the most varied, simple and complex conditioned reflexes. This is explained by the fact that man is not merely a biological being with a highly-developed central nervous system, but a social being as well. His behaviour is not only determined by the usual excitors of the outer world that act on his hearing, eyesight, sense of touch, smell, and others, but by specific excitors peculiar to man alone. They are words.

The sensations and notions arising in the brain from ordinary sensory excitors of the outer world are signals of the environment, as it were. They may therefore be called the first system of signals, and exist in both men and animals.

Words also serve as signals. But they are signals of a special type, signals that supplement ordinary sensations and notions. Signals of that type arise from abstracting and generalizing definite properties of various objects. When we pronounce the word "apple," for instance, we may not have an apple in front of us. But we may, nonetheless, experience everything that usually occurs at the sight of a real apple: a sense of hunger, and salivation. The word "apple" serves as a symbol of those specific excitors, those signals of reality, as Pavlov puts it, which are peculiar to a real apple and are bound up with its colour, taste, and fragrance.

The written or spoken word, therefore, is fraught with all the consequences subject to the usual laws of conditioned reflexes.

Words, however, are connected with the mental activity taking place in the cerebral cortex. Indissolubly bound up with words, this also comprises a system of signals—the second, or language system of signals.

Here is an example. You are at your friends', and are absorbed in conversation. A member of the household comes into the room and says that dinner is served. You were not thinking of food the moment before, you saw no food, and did not hear the rattling of spoons and plates. All the ordinary excitors of the conditioned food reflex are absent. But in spite of that you suddenly experience a sense of hunger, you feel your appetite rising, your mouth watering.

Your reaction is induced by word of mouth. It is not supported by visual, acoustic, taste, or other sensations associated with food. It is built upon purely psychological notions. The conditioned reflex is actuated by the second signal system.

Here is what Pavlov said about it:

"When the developing animal world reached the stage of man, an extremely important addition was made to the mechanism of the higher nervous activity. In the animal, reality is signalized almost exclusively by stimulations and the traces they make in the cerebral hemispheres, which directly lead to the special cells of the visual, auditory or other receptors of the organism. This is what we too possess in the shape of impressions, sensations and ideas of the world around us, both the natural and the social—with the exception of oral and written speech. This is the first system of signals of reality, common to man and the animals. But speech constitutes a second system of signals of reality which is peculiarly ours, and is a signal of the first signals."

Pavlov voiced a similar idea in his report to the 14th World Physiological Congress in Rome in 1932: "Our sensations and notions of the outer world are for us the first signals of reality, while speech, and especially irritations transmitted to the cortex from the organs of speech, are the second signals, or signals of signals. They represent an abstraction from reality and allow of generalizations, constituting our extra, specifically human, higher mentality, creating first an empiricism general to all men and then, in the end, science, the instrument of the higher orientation of man in the outer world and in himself."

The word plays an extraordinarily important part in the life of every human being. In medical practice, where the patient must be questioned, oral instructions are given, and the doctor exercises his influence by word of mouth, the second signal system is also of great significance. It acts as an excitor of a great many complex physiological mechanisms.

Animals do not have the second signal system. That is quite natural, because animals have no abstract notions. A dog which prostrates itself on the command of "down," does not understand the meaning of the word itself. It drops to the floor because a conditioned reflex has been evolved in it to a certain combination of sounds, to an acoustic excitor of a definite tone and force. If the same command is given in other words—"drop to the ground," for instance, or "assume a lying position"—the dog will ignore it. There will be no conditioned reflex reaction, because the dog will not "grasp" the meaning of the words. It only has the first system of signals, and the acoustic excitation of "drop to the ground" has not as yet evolved a conditioned reflex in it.

Man, on the other hand, has both the first and second systems of signals. In man conditioned reflexes are activated by visual, acoustic, and taste excitors of the first system of signals, and excitors contained in the symbol of words, words that are spoken, written or heard, and which are associated with the second system of signals.

Combinations of word excitors may tie up with other, previously acquired word excitors to form extremely complex chains, or associations. Such combinations constitute the form of our thinking.

Naturally, the first and second systems of signals are not isolated from each other. They are closely interlinked, and exert a mutual influence. It should also be recalled that verbal thinking is tied up with imaginative thinking.

At the same time the word is to man as real an excitor of conditioned reflexes, as any factor—bell, light, or the sound of footsteps—of the outer world is to an animal.

Pavlov brought to light one more physiological mechanism of the higher nervous activity.

IMPORTANT FEATURES

THE TWO TYPES OF NERVOUS activity established in man in connection with the first and second systems of signals do not by any means solve the problem. Men break up into two groups by the predominance in them of either the first or second system of signals. But that is not all. Their nervous activity may have distinctive features bound up with the nature of its basic processes—excitation and inhibition. These also form various types of nervous activity.

Here we arrive at a salient point in Pavlovian physiology. The principal properties of nerve tissue are its faculties of excitation and inhibition. The one and the other in their various combinations constitute the most essential aspects of the higher nervous system.

In his countless experiments and investigations of dogs Pavlov determined that the processes of excitation and inhibition are not the same in all animals. They differ in intensity, speed, and mutual relation.

By the intensity of their processes, the intensity of excitation, the types of nervous activity break up chiefly into two main groups—strong and weak. The strong type, in its turn, breaks up into several groups: strong excitable unbalanced, strong excitable balanced, and strong calm balanced, which are distinguished by the speed of the processes in the cerebral cortex, the balance of excitation and inhibition, and by the predominance of either the one or the other. The weak type, meanwhile, has sluggish excitation and inhibition processes.

These types of the higher nervous activity were physiologically confirmed by Pavlov in his investigations of dogs. The question was whether they also applied to human beings. Pavlov said that they did.

"The question of the types of nervous systems is of the utmost importance to all of us... We must regard this as an accurate fact. We have every reason to apply the types of nervous systems established in dogs to human beings... This conformity of facts in man and animal speaks convincingly of the validity of this classification and the accuracy of this gradation."

It is extremely difficult to determine the type of nervous activity in individuals. But their behaviour in various circumstances at home, at work, and in their social life, offers certain clues.

The strong type is distinguished by its ability to withstand difficulties and overcome obstacles, by its show of initiative, perseverance, and courage. In doing a job that entails a great effort the strong type carries it out with a will and a sense of satisfaction at surmounting difficulties.

A person of the weak type, meanwhile, tends to avoid difficulties and dangers.

The difference in the intensity of the nervous activity is evident in public speeches, for instance. The strong type speaks with great resolution and challenge, and seeks to attract the greatest possible attention. The weak type, on the other hand, wants his speech to pass unnoticed.

The strong type readily tackles difficult and complicated problems; the weak type avoids them. He is rather attracted by goals that do not entail great effort.

The strong type is stubborn in a struggle, while the weak type seeks to avoid a fight. The very thought of struggle torments the weak, and he gives in easily.

But specimens of the strong type are not all the same. Some can hold their passions in check. Those are of the strong balanced type, in whom excitation is balanced by inhibition. In others an outbreak of excitement is uncontrolled. These are of the strong unbalanced type, in whom excitation predominates over inhibition. They are impatient, quick-tempered and irritable, and lack self-command.

But this does not exhaust the classification of types of the higher nervous activity. There are many sub-divisions. An individual of the strong balanced type may adapt himself readily to changing circumstances, to revise his habits with ease, and fit himself into new, even difficult conditions. That is a lively strong type of nervous activity.

The inert type is different. His habits are lasting. They change slowly. He adapts himself to new conditions very slowly and unwillingly. Moving to a new flat, even moving furniture in his room, seems difficult and complicated to him.

Such is the outline of Pavlov's teaching on the types of nervous activity as applied to man.

THE ENVIRONMENT

THE TYPE OF THE HIGHER nervous activity is not insusceptible of change, or pre-destined from the moment of birth. The main features of the nervous activity may change, changing the type itself, changing its qualities, and the behaviour of the living being. This is done by the outer surroundings and the situation. Types are created above all by the environment, by the living conditions.

An experiment was made with a litter of pups. Soon after birth they were broken up into two groups. Each group was put into a different environment.

The pups of the first group lived out in the open. They were allowed to run about the yard, encounter other dogs, associate with human beings, and play about without restraint. The pups of the second group were kept in a cage almost all the time.

They grew up and were subjected to experiments involving conditioned reflexes.

It turned out that the dogs of the first group, reared out in the open, had little in common with those of the second group. They were cheerful, sociable, and inquisitive. Their reactions to conditioned excitors were normal.

The dogs raised in seclusion behaved quite differently. They cringed at the sight of other animals, or strange people. Their movements were inhibited, and sharp noises caused them to tremble. They behaved as though unseen dangers lurked all about them. Every unexpected and strange little thing frightened them.

This highly instructive experiment confirmed that behaviour and character are forged by the environment, upbringing, and living conditions. It was also clear that the various types of nervous activity, and the reactions of living beings to phenomena of the outer world, were all shaped by these factors.

A NEW WORLD

THE FORMER CONCEPTION of two independent systems of organs—of volitional activity governed by the cerebral cortex, and unconscious activity governed by autonomous, vegetative nerves—in the bodies of living beings, and particularly mammals and human beings, was shattered once and for all.

Proceeding from Pavlov's works, Academician Bykov and his associates studied the laws of the relationship of internal organs and tissues, and the higher levels of the brain.

Countless experiments were performed to study other functions of the body, such as metabolism, expansion and contraction of blood vessels, and such periodic phenomena as sleep, the daily rhythm of bodily temperature, and the automatic function of the respiratory apparatus.

The clever and painstaking experiments sometimes yielded astounding results. The touch of cold objects, for instance, was made to cause a sensation of warmth, and vice versa. In some experiments the blood vessels in a hand lowered into hot water contracted, instead of expanding. The skin was made insensible to pain reflexes from strong irritants. All these unusual phenomena were built upon conditioned reflexes and the participation of the cerebral cortex.

It was clear that the body was not a mechanical combination of two independent spheres. It was a single whole, whose parts were governed and co-ordinated by a single higher nervous mechanism—the cerebral cortex.

Physiologically speaking, that is just as it should be.

Faced by a sudden danger a living being must either turn and flee, or summon its strength to attack its foe. But the body muscles alone cannot accomplish either. The heart must be mobilized, the spleen must contract and eject its blood reserves into the general stream, and the adrenals must intensify their function to secrete more adrenalin, which, in its turn, increases the consumption by the muscles of sugar, that source of energy. The remaining organs must also take an active part in the body's struggle for safety. And that is exactly what happens. It is an age-old adage that strength multiplies in times of danger. At such times a man is able to jump a fence, for instance, which he would not have been able to negotiate under ordinary circumstances, or resist a stronger adversary, who would easily have overpowered him at another time.

To put all the organs, internal and external alike, into simultaneous operation at short notice, they must be governed by a single centre. It is this oneness of all their functions that preserves and develops life, and creates the most favourable conditions for the body's adjustment to its environment.

The research at Bykov's laboratory, which is a development of Pavlov's teaching, reveals the actual nature of the controlling part played by the cerebral cortex, whose cells receive all the signals of the outer world through the sense organs.

GREATER SECURITY

LIGHT WAS SHED ON ANOTHER curious phenomenon observed by the investigators.

Let us recall the experiments with the denervated thyroid gland, which revealed a remarkable thing: impulses from the cerebral cortex reached the gland both along the nerve fibres, and through the hypophysis. The hormone of the hypophysis was secreted into the blood and reached the thyroid gland. That, as we have said, is a humoral connection.

The same was true for the kidneys, spleen, blood vessels, and many other organs. Their nerve connections with the cortex were cut. Yet the conditioned reflexes functioned. Signals from the higher nervous centres reached the effector organs through the hypophysis, the adrenals, and certain other endocrine glands.

This dual connection between the cortex and the outlying organs has a great vital expedience. The co-ordinated unintermittent control of the body organs was evolved in the struggle for survival, and by natural selection in the course of millions of years. Natural selection, that formidable factor of development, forged co-ordinated, accurate, and swift defence reactions, and shaped their preparedness and adaptability to the constantly changing conditions of the environment.

The supplementary humoral type of connection, which exists alongside the all-embracing and leading nervous network, facilitates the struggle for survival, protects the safety and life of the body. To put it in Bykov's words, it is to be regarded as a "phenomenon of the utmost in organization, which ensures the most complex manifestations of life."

SIGNALS TO THE CENTRE

WE ARE ALL FAMILIAR with those indistinct, "murky" sensations, vague and unaccountable, that arise somewhere in the depth of our bodies. We may be perfectly well, and yet feel out of sorts. The condition often passes tracelessly, but sometimes it develops into a distinct indisposition, and doctors soon discover disorders of the liver or heart, the kidneys or lungs.

It is to be presumed that they all begin with some derangement. Certain processes in the depths of the body become disordered. The organs concerned send unusual impulses to the cerebral cortex. It is these unusual impulses that give rise to the "murky" sensations.

It follows that the cortex not only sends out orders to the internal organs, but receives their signals as well. The cerebral cortex, our psychic world, our consciousness and will, not only influence the work of internal organs, but are themselves under a certain influence of incoming impulses. That is what Pavlov's followers say. They not only say it, but prove it in a series of interesting experiments.

Ivanova and other associates of Academician Bykov, for instance, performed the following investigation. With the aid of an operation they formed a stomach fistula and gained access to the stomach through the abdominal wall. The operation was successful. The dog was soon as good as normal.

Water was poured into the stomach through the fistula, and was then immediately drained. This, in effect, was nothing more than an irrigation. The dog's hind leg was simultaneously irritated with electric current. The shock caused the leg to jerk back, evolving a defensive reaction.

After some ten such combinations the dog would jerk back its leg whenever water was being poured into its stomach, although the electric current was not applied. We know what that was. It was a conditioned reflex. But at the moment we are interested in another aspect of the experiment.

The conditioned excitor was water irrigation. The walls of the stomach, therefore, are equipped with receptors, or nerves that receive irritations and transmit them to the cerebral cortex. If there had been no such receptors, there could not have been a conditioned reflex. Anatomists and physiologists have not as yet exhaustively studied the structure of these receptors, but proof is available that they exist. They were discovered by Lavrentyev, a prominent Soviet scientist.

The receptors in the walls of the stomach, i.e., in the tissue of an internal organ, are known as interoceptors as distinct from exteroceptors, or external sensory nerve endings.

Since there are interoceptors, there must also be nerve conductors transmitting their impulses to the cerebral cortex. The experiment thus shows that the stomach not only receives signals from cortical centres, but in turn sends its own impulses along the nerve fibres.

THE SAME PROPERTIES

THE INVESTIGATIONS OF AIRAPETYANTS, a pupil of Academician Bykov, occupy a special place in visceral research. His complicated and clever experiments yielded interesting results.

The investigator produced a stomach fistula in a laboratory dog. He also drew out the duct of its salivary glands. The saliva poured through a little funnel into a measuring cylinder suspended at the corner of the animal's mouth. The cylinder recorded the quantity of secreted saliva by the usual Pavlovian method.

A tube was inserted into the stomach fistula. But it was not only a matter of filling the stomach with water. Two thinner tubes were placed into the first. The water poured into the stomach under a certain pressure through one of them, and poured out of it through the other.

The stomach was irrigated with water for 45-50 seconds. Simultaneously, the dog was given meat-and-rusk powder much liked by animals and causing intense salivation. The meat was fed from a special automatic feeder. No attendants were present, and the silence in the laboratory was complete.

The irrigation lasted as long as the dog ate. As soon as it ceased eating the irrigation ceased too. In Pavlovian terms this meant that the excitation of the walls of the stomach by irrigation was being supported by food.

The procedure was repeated several times.

Then the experiment was changed. The dog was left alone again, and there was the same perfect silence. The irrigation of the stomach was repeated, but the meat-and-rusk powder was withheld. In spite of that intense salivation began twenty seconds later.

It is easy to see what happened. The salivation was induced by a conditioned reflex. The cells that transmit signals to the salivary gland are in the cerebral cortex. The signals were actuated by the irrigation of the stomach. Only nerve receptors, or interoceptors in the stomach wall could be irritated by water and transmit impulses to the higher nerve centres. Conditioned reflexes evolved by means of internal excitors show that the interoceptive connection of the organ and brain gives rise to a cortical process identical to processes called up by impulses from the exteroceptors, or sense organs.

But many other processes, such as inhibition, differentiation, and irradiation, accompany conditioned reflexes set off in the cerebral cortex by external excitors. Was the same true for interoceptive impulses, for signals from internal organs? Airapetyants's experiments, and the investigations of other researchers, showed that it was.

They evolved an interoceptive conditioned association between an animal's stomach and the cerebral cortex. After several irrigations of the stomach, supported by meat-and-rusk powder, salivation was provoked without the food. Everything went off as it should. But in one of the experiments the saliva did not run.

Everything had been done just as in the preceding experiments—first the association of irrigation and food, and then irrigation without food. But time went by and not a drop of saliva appeared in the measuring cylinder.

There was a new element in the experiment. The feeding had been geared to irrigation of water at 97^0 F. This time, however, when food was not given, the water was only 79^0 F. It was this that made all the difference. Irrigation with cold water did not induce salivation. On the contrary, it stopped it. The conditioned reflex in the cerebral cortex was inhibited.

It follows that apart from evolving conditioned reflexes, interoceptive impulses can also suppress them. What is more, they are capable of differentiation, in this particular case the differentiation between water at 97^0 supported by food from water at 79^0 unsupported by food.

It is certain that interoceptors possess the same principal properties as exteroceptors.

The discovery of that was an important milestone in the physiology of the higher nervous activity.

BORDERS PUSHED BACK

ALL THESE FINDINGS may have been highly significant, but they only spoke of what occurred in a single organ—the stomach. It could be inferred, of course, that the stomach was not an exception: what was true for the stomach, should have been true for the other internal organs. But science wants proofs. It had to be proved that other internal organs also send signals to the brain. Isolated facts would then become a general conclusion, giving grounds to formulate a physiological law.

The intestines were the next object of study.

Physiologists have a way of isolating an intestinal loop. It is done by excising a section of the intestine. The cut piece does not die. Its nerve fibres and blood vessels are preserved. Its connection with the nervous and vascular systems remains. Its nutrition and nervous regulation continues, although the section itself is isolated from the rest of the intestines. The two ends of the isolated loop are drawn out and sewn to the incised skin. The continuity of the intestine in the abdominal cavity is restored. After the wound heals the animal returns to normal, eats, drinks, and sleeps as other dogs, while the isolated piece of intestine is at the disposal of the experimenter.

This method was repeatedly used by Bykov's associates in their investigations. Airapetyants, who tackled the question of intestinal interoceptors, also obtained illuminating results.

He placed a small rubber balloon into the isolated intestinal loop, and poured water into it at 43^0F, simultaneously applying electric current to the animal's hind leg. The current came in the wake of the water, making the leg jerk. After this was repeated several times, the electric current was withheld. But in spite of that the leg jerked whenever water filled the little balloon. It was a conditioned reflex. The walls of the intestine sent nerve signals to the cerebral cortex. The interoceptive connection between intestine and cortex became an established fact.

Other experiments with the isolated intestinal loop led to the discovery of new phenomena linked with interoceptive impulses. One of these ingenious and extremely convincing experiments, made by Vasilevskaya, is described below.

The isolated piece of intestine was irrigated with a weak solution of hydrochloric acid at a certain temperature. Simultaneously, the dog was fed meat-and-rusk powder. Several dozen times of this were enough to evolve a reliable conditioned reflex. Saliva, actuated by the conditioned reflex, flowed liberally as soon as irrigation began, although food was no longer given.

Then the experiment was changed. Ordinary tap water was used instead of the hydrochloric acid solution. The water was of the same temperature as the acid before it.

There was no salivation. The intestinal interoceptors transmitted impulses to the brain, but the cortical cells of the food centre appeared to know the difference between them and the signals sent by the hydrochloric acid. The conditioned reflex remained dormant.

It followed that the interoceptive impulses of the intestinal wall not only excited reflexes, but were attended by the other cortical processes, such as differentiation and inhibition.

FURTHER STEPS

A STUDY OF SUCH ORGANS as the stomach, intestines, kidneys, the bladder, etc., showed that they also had receptors. But there are important processes linked with entire physiological systems, and not only separate organs.

There is the cardio-vascular system, for instance, which is of an all-embracing significance. Do vessels, too, have interoceptors?

The investigators faced a difficult task. The very idea of experimenting with blood vessels appeared highly complex. They would have to find new ways, new methods, new means of acting upon the walls of arteries and veins.

There is one factor in blood circulation that is of vital importance to the body. It is blood pressure. In a sound organism it is more or less constant—about 130-140 millimetres of the mercury column in a middle-aged man. In heart disorders it is either higher, or lower, and sometimes greatly so. A protracted, and particularly a permanent change in blood pressure is a sign of grave disorders in the heart, alterations in the blood vessels and the elasticity of arteries.

The various departments of the cardio-vascular system are closely interconnected. Changes in the minutest vessels and capillaries reflect on the heart, on the frequency of its beats and the amplitude of its contractions. Conversely, the condition of the heart, the heart rhythm, the filling of auricles and ventricles, and the force of the ejected blood—all reflect on even the smallest of vessels and capillaries, to say nothing of the major vessels. Disorders in one department of the cardio-vascular system may cause compensatory changes in another. This makes for the normal activity of the entire blood system.

The co-ordinated work of the heart and vessels has long since attracted the attention of investigators. They wanted to know how the various departments of the cardio-vascular system are regulated.

The aorta is the largest blood vessel. The pressure in it may rise. That, naturally, deranges the blood circulation. But this state of affairs is speedily remedied. The heart reacts to it by slowing down. The number of its beats decreases. As a result, less blood is pumped into the aorta, and the pressure approaches normal, precluding the possibility of morbid effects in the body.

The blood pressure may also rise in another major vessel—the carotid artery. That is a serious disorder. The branches of the carotid feed the brain. A sharp rise in blood pressure may rupture some little artery, and cause death. But usually nothing of the kind happens. The heart instantly slows down, and the pressure returns to normal.

Blood is conveyed to the heart by the superior and inferior venae cavae. Accumulating in the latter close to the heart the blood dilates their walls. Its pressure rises. If there is much blood in the venae cavae, there must be little of it in the heart cavity. A blood shortage may derange the work of the heart and threaten life. But as soon as the venae cavae are dilated the heart intensifies its work. It pumps the blood over into the aorta, the pulmonary artery, and onward into the other arteries. The blood leaves the venae cavae, the pressure in them drops to normal, and the cardio-vascular system resumes its customary rhythm.

Investigators wanted to know how all these adjustments took place, why the heart beat stronger or weaker as the occasion demanded, and how to explain the adaptability of the heart to whatever happened in the major blood vessels. In the latter half of the last century they discovered the mechanism which regulated these phenomena. The walls of the aortic arch next to the heart, the venae cavae close to their junction with the heart, and a certain point of the carotid artery contain formations sensitive to blood pressure and its changes. They are, in effect, nerve endings, or interoceptors, leading from the brain centres. The blood pressure within the major vessels is recorded by the interoceptors. Corresponding impulses are transmitted along nerve fibres to the brain centres, and from there to nerve conductors that either accelerate, or slow down the heart beats.

The function of the heart is geared to the normal requirements of the body at any given moment. All that was long since determined. But for a time the research in this sphere went no further. Investigators failed to locate interoceptors in the blood system outside the aortic arch, the venae cavae, and the carotid. The task fell to Bykov and his associates.

REGULATED PRESSURE

THE GOAL WAS DIFFICULT to achieve. The investigators stood in need of a reliable method that would enable them at will to regulate the pressure in any vessel of any organ.

They found such a method. It was the method of perfusion. Perfusion implies an act of pouring over or through.

Chernigovsky, Bykov's closest associate, made use of perfusion in his experiments with the vessels of the spleen. He isolated the spleen of the experimental animal from all the body fluids; not a single drop of blood could reach it. All the arteries and veins entering or leaving it were clamped. The neural lines of communication, meanwhile, were left intact. The neural association of the spleen with the body was fully preserved, while its arteries and veins, isolated from the general circulation, were empty. It was ready for perfusion.

A saline solution saturated with oxygen and containing a number of important salts was poured through the vessels of the spleen. The solution took the place of blood. Not a drop of it escaped into the general blood stream. Its pressure in the vessels of the spleen could be increased or decreased at will with the aid of special instruments.

The neural association of the spleen with the rest of the body, as we have said, remained intact. Hence, if the spleen's arteries and veins should have interoceptors recording the pressure of the perfusate on their walls, the impulses would be transmitted by the nerve fibres to the central nervous system and would cause a reflex reaction on the part of the entire cardio-vascular system.

That is just what happened. Whenever the pressure of the perfusate in the vessels of the spleen was increased, the pressure in the arteries leading away from the heart—the carotid, for example—dropped accordingly. Conversely, a decrease in the pressure on the spleen's vessels caused a rise in the pressure of the general blood stream.

Perfusion experiments on other organs performed by Chernigovsky, Rikl, Delov, Lebedev, Arkhangelskaya, and Merkulova, confirmed the results obtained in the experiment with the spleen. The various phenomena observed in the intestines, liver, kidneys, stomach, and pancreas could only be explained by the presence of interoceptors in the walls of the vessels of these organs, which sent impulses to the cortex and influenced the function of general physiological systems, such as the cardio-vascular and respiratory systems.

Varying in form, cortical reactions testified to the presence of interoceptive formations in the blood vessels and in the tissues of internal organs.

ACTION OF HORMONES

The interoceptors influenced by the blood pressure are known as baro-receptors. But there are other receiving nerve mechanisms in the walls of vessels. Investigators came across phenomena linked with the reaction of cortical centres to chemical substances produced within the body in the process of its activity and secreted into the blood of various internal organs.

The assumption that nervous activity is accompanied by the formation of acetylcholine, for instance, and that the latter takes a part in it, can be proved. A negligible quantity of acetylcholine in the vessels of the spleen causes a steep, though short-lived, rise in the pressure of the entire blood system. Simultaneously, respiration is intensified, and becomes quick and deep. Acetylcholine has a similar effect on the vessels of the intestines, kidneys, and certain other organs. The explanation, it appears, is that the vessels of these organs have interoceptors in their walls that react to chemical substances such as acetylcholine. They are called chemo-receptors, and transmit to the cortex impulses engendered by chemical agents. From there signals are sent to the nerves that accelerate heart beats and intensify respiration.

The experiments with substances produced by the internal organs themselves, particularly endocrine glands, are of special interest.

Adrenalin is secreted by the adrenal glands. A negligible quantity of that hormone in a spleen perfusion soon caused changes in the heart and respiration: the pressure in the aorta, carotid, and other major vessels rose, and respiration became deeper, and accelerated.

But when the same dose of adrenalin was added to the solution perfused into the adrenal gland, the picture changed: the blood pressure in the carotid, for instance, dropped, while the frequency and depth of respiratory movements increased.

And an identical dose of adrenalin in the jugular vein, which adjoins the carotid artery, caused a sharp increase in blood pressure, while the respiration, which, it would appear, should have intensified, slowed down, and the respiratory movements shrank.

Similar experiments with the thyroid gland and pancreas showed that the action of hormones on the vessels and tissues of the endocrine organs themselves causes changes which are unlike those that they cause when introduced into the general blood stream.

It is to be assumed, therefore, that organs of internal secretion not only produce hormones, but possess interoceptor nerve endings, which send impulses set off by hormones to the cerebral cortex. These nerve endings are located in the walls of vessels and, probably, in the tissues themselves.

That is an important conclusion yielded by the above experiments. There is another. The same internal excitors, it turned out, caused different reactions in the body. Their influence on physiological processes depended on their place of application, on the properties of the particular interoceptors concerned. Adrenalin in the spleen raised the blood pressure, while the pressure dropped when adrenalin was introduced into the adrenals. Its action on the body is, presumably, beneficial in one case, and harmful in the other.

That is a fact of extraordinary importance. It sheds new light on such vital substances as hormones, and on their worth as therapeutic factors.

There are grounds to agree with Bykov that it possibly "offers a new mode of action against pathogenic agents," and that even the initial findings "hold a promise of an abundant harvest of new facts and conceptions."

NEW PROOF

THE DISCOVERY OF THE CLOSE connection between the cortex and the internal organs was a major event in physiology. No less important was the discovery in the cortex of "representatives" of the internal organs, which bombarded the brain with impulses. The cerebral cortex, it appears, influenced the work of the internal organs, and these, in their turn, affected the function of the cortex. A ceaseless stream of signals informed the brain of the condition, work, processes, and disorders in the internal organs, formed temporary associations, conditioned reflexes, excited and inhibited them. The mechanism which adjusted the work of the internal organs, which helped them to adapt themselves to the conditions and requirements of the outer world, was found. It explained the unity of the higher nervous system and the internal milieu.

Years of research by Bykov and his numerous associates established the existence of interoceptors, and of the nerve channels that conveyed impulses from the internal organs to the brain.

But the picture was still incomplete. The experiments gave every reason to believe that there really were interoceptors. In the final analysis, however, this was nothing more than a logical conclusion. To become a scientific fact it had to be experimentally substantiated. If the investigators could only at will eliminate the interoceptors, or deprive them of their receptive faculties, that would be convincing enough.

Bykov's laboratory tackled the problem, and succeeded with the help of novocain.

A section of a dog's intestine was drawn out to the surface, and a fistula was made in it. A weak solution of hydrochloric acid was poured into the intestine through the fistula. At the same time, the dog was fed meat-and-rusk powder.

Soon the solution of hydrochloric acid alone, without the food, actuated the salivary glands. Saliva poured freely. The conditioned reflex was fully evolved.

A solution of novocain was then substituted for the acid. The conditioned reflex vanished. What is more, hydrochloric acid had no effect on the salivary glands long after the novocain irrigation. Novocain is an anaesthetic, a substance that makes tissue insensible to pain and other sensations. It acts exclusively on nerve tissue. In this experiment it paralyzed some nerve agents in the walls of the stomach, and made them insensible to hydrochloric acid.

These agents could only have been nerve endings, or interoceptors, in the walls of the stomach.

Under novocain the stomach interoceptors lost their sensitivity; they were inhibited and did not respond to the conditioned excitor. As a result, it disappeared.

Chernigovsky utilized the same method in his experiments with the vessels of the spleen. Let us recall them. A perfusate was introduced under pressure into the vessels, and the blood pressure dropped in the major arteries leading from the heart.

But when a solution of novocain was added to the perfusate only the pressure in the spleen increased. Nothing changed in the major arteries. The pressure in them remained at its usual level. It followed that the walls of the spleen vessels had nerve endings. The novocain paralyzed them and ruled out conditioned reflex reactions.

Experiments with the vessels of the intestines, the pancreas, adrenals, and other internal organs, yielded the same results. Novocain, which paralyzed the nerve endings, confirmed the presence of interoceptors in the walls of vessels and the tissues of organs.

THE THRESHOLD

THE PICTURE WAS CLEAR. Internal organs took orders from the cerebral cortex. In their turn, they sent impulses to the cortex and affected its activity, influenced consciousness, psychology, will, and behaviour.

Sechenov's words are now better understood. More than fifty years ago the noted Russian physiologist wrote about the "murky sensations" within us that we cannot identify with either the stomach, liver, or any other organ.

There is the question why we are unaware of the stream of impulses from the internal organs to the cortex, that centre of our consciousness, why we do not feel them, and do not know of them. Would it be better to know each second of the state of our liver, stomach, spleen, kidneys, adrenals, pancreas, thyroid, and the vessels?

No, that would be disastrous. The ceaseless stream of signals to the brain would fill it with a chaos of sensations. There would be no room for anything else. It would distract animals from the realities about them; they would be helpless in the face of the outer world. The same is true for human beings.

It is a good thing that interoceptive signals reach no farther than the threshold of consciousness, and pass it on rare occasions only. That is the result of millions of years of natural selection, and should be regarded as a protective adjustment of living beings to their environment. The psychic regions of the cortex admit only signals—both of the external and internal world—essential at any given moment. The brain does not respond to all signals indiscriminately; many of them are inhibited.

A RIDDLE NO MORE

THE ENGINEER WAS a perfectly healthy man. He had no complaints. But strangely enough he fainted whenever he heard the shrill sound of an automobile horn. Nothing could be done about it. Other, less piercing blasts did not affect him.

He had seen a lorry knock down a pedestrian. The driver had sounded the horn in a last, desperate piercing blast, but it had been too late. The pedestrian, extracted from under the lorry, was a mangled heap of bones and blood, at whose sight the engineer fainted. Ever since then he fainted every time he heard a piercing automobile horn. The doctors could only shrug their shoulders. They regarded him as a high-strung, hypersensitive individual.

The young stenographer's husband told her they had to part because he loved another. It was a cruel blow. The room where he told her this, was in semi-darkness. She felt her throat constrict, and gasped for breath. There was also an acute, painful spasm in the pit of her stomach. Since then the spasm returned every time she saw two figures, male and female, in the dusk of a quiet street. The pain was so acute it virtually made her cry.

The doctors prescribed bromide, rest, and stomach diathermy. Nothing helped, and they urged her to fight her idle obsession. But their advice was futile.

One day a gardener was transplanting yellow dahlias. A sudden fit of nausea overcame him. And ever since objects of a yellow colour nauseated him.

Neuropsychiatrists know of numerous unexplainable and strange cases. Past events that have long lost their import become sources of ailments, aches, and unappeasable suffering.

Many patients approach doctors with seemingly groundless complaints. There are no visible derangements in their bodies. They are told to ignore whatever bothers them, and are prescribed palliatives. But it is all no use. The sufferings continue.

Pavlov's teaching and the investigations made by Bykov shed light on these cases. The complaints are not groundless. Certain circumstances of the outer world which happen to be associated in the mind of a patient with some striking past event, serve as an excitor of a conditioned reflex.

Bykov utilized Pavlovian methods to substantiate the teaching of the great physiologist, who showed that the soma, the world of internal organs, the world of vegetative processes and neuro-psychic life are a single whole. Neuro-psychic phenomena are capable of affecting and upsetting vegetative processes.

The story of the American financier and his diabetes should no longer puzzle us. In plain words, the stock exchange crash had upset the activity of the cortical centres, and that, in turn, deranged the vegetative processes and, notably, those of the pancreas, which secretes insulin.

In the light of Pavlov's teaching many riddles are riddles no longer.

DISASTER OVERCOME

THE AIRMAN WAS SHOT DOWN in a dog-fight. He was seriously wounded in both his legs. Running the risk of being discovered by the enemy, and summoning up his remaining strength, he crept back to the Soviet lines, and was sent to hospital.

His life was saved, but both feet had to be amputated. The airman—fearless, strong, resolute—became a cripple. The heavenly expanses were not for him any more. He would never again pilot an aircraft. The tragedy, it appeared, could not be helped. Everything was over for him.

He suffered mental anguish. Days passed slowly, the wounded tissues healed slower still. Then an amazing thing happened. In a few months the airman took his place at the controls of a powerful fighting machine. His depression, which could have kept him in bed indefinitely, vanished without a trace. Even an experienced eye was unable to distinguish the artificial limbs he wore from his amputated feet. He flew as he used to fly before, nimble, fearless, and forceful. His pursuit plane was a terror to the enemy. He shot down eleven fascist aircraft.

That is the plot of Boris Polevoy's book, *A Story About a Real Man*, which tells the true tale of airman Meresyev.

His convalescence, which could have taken years, was shortened by the airman's desire to get well, by his thirst for life, his resolution to surmount weakness and perform his duty. He summoned up all his will and energy to overcome his handicap.

Pavlenko's *Happiness* tells a similar story. A Soviet Army colonel, doctors found, had tuberculosis of the lungs. The disease was advanced. The colonel was sent to the Crimea. He was to spend some considerable time there on a rest cure. He was in no case to do any work and expose himself to fatigue. His life was in danger. There could be no question of breaking doctor's orders.

Several months passed, and the colonel was busy at work. He could not stay idle with so much work about him, and took an active part in rehabilitating the economy of the war-ravaged district.

There was no potent drug to check his disease. It was the colonel's moral strength that did it. He forgot about his ailment, and the ailment appeared to forget him in its turn. It retreated, as it were, before an all-powerful thirst for life, major successes, the joy of creating, the effort to build a new, wonderful life. The man conquered his disease with his enthusiasm, his will, his sense of duty, and with the happiness of taking part in a common effort.

The two authors scarcely deserve to be accused of stretching the point too far, not after what we have learned of Bykov's findings on the influence of the cerebral cortex upon processes in body tissues. The writers' imagination has not sinned against scientific knowledge. That does not mean, of course, that enthusiasm, inspiration, moral strength, and good cheer are panacea. It only means that the mental condition of the patient has an unquestionable influence on the course of his disease.

ONSET OF NEUROSIS

THE BLOOD VESSELS CONTRACT from cold, and expand from heat. At Bykov's laboratory a man's hand was thrust into a receptacle with a spiral tube. Cold water was passed through the tube, and the hand turned pale. Its vessels contracted. That was an unconditioned thermal reflex.

Then the experiment was changed. Every time cold water was passed through the coil a metronome was turned on at 120 strokes per minute. After twenty such combinations the metronome's strokes became a conditioned excitor. The blood vessels contracted at their sound even in the absence of cold water.

Another test was made. This time hot water was passed through the coil. The skin of the hand turned red. Its blood vessels expanded. A red lamp was switched on simultaneously to evolve a conditioned reflex. Soon the red lamp alone was enough to make the vessels expand.

The cerebral cortex, as we know, takes part in forming conditioned reflexes. That can be verified in the following manner. After the combination of cold water and metronome had been repeated twenty-five times, for instance, and the conditioned reflex was stable enough, the metronome was turned on at 60 strokes per minute, and had no effect whatsoever on the colour of the hand. The skin did not turn pale. Its blood vessels did not contract. The conditioned reflex evolved with 120 strokes per minute would not respond to 60 strokes. The same thing was observed when a green lamp was substituted for the red. The sixty strokes and the green light gave rise to phenomena of differentiation and inhibition. And processes of that kind could only originate in the cerebral cortex.

New conditions were then introduced. Previously a series of consecutive unconditioned irritations with cold and conditioned irritations with the metronome, preceded a series of unconditioned irritations with warmth and conditioned irritations with the red lamp. Now they were all haphazardly mixed. The combination of cold and the metronome was followed directly by the combination of warmth and the red lamp. The cold water was accompanied by the metronome and the vessels contracted, and then came the red lamp and warm water, and they expanded. And thus time after time, and all haphazardly. A rhythmical succession of events gave way to disorder.

The muscles and nerves of the vessels had to cope with an onerous assignment. They were in a sustained state of tension. Strange phenomena set in. At the sound of the metronome the vessels suddenly expanded instead of contracting, while the red light made the skin of the hand turn pale. Everything was in a turmoil. The reactions of the vessels to cortical impulses were anomalous.

An ailment began, which is known as angioneurosis.

The experiment sheds light on at least one of the causes of angioneurosis—excessive excitation and haphazard alternation of conditioned excitors.

The normal function of the stomach is dependent on the normal function of the glands in the abdominal cavity, on the proper secretion of gastric juice. The composition and quantity of gastric juice depend on the nature of the food, on its taste and other qualities. On reaching the stomach food excites the interoceptors in its walls, and their impulses to the cortex activate the glands which secrete gastric juice.

In experiments dogs were fed sugar and honey. Soon changes were observed in their gastric juice. An ingenious investigation revealed that the glands are located in three regions of the stomach—the lesser curvature, the greater curvature, and the pylorus. Changes were recorded in the glands of all three regions. First the total quantity of gastric juice decreased, and then its composition changed sharply. The hydrochloric acid vanished, and the secretion took on the appearance of a blood-like fluid which little resembled normal gastric juice. The dogs refused the sweet food. Their digestion was disordered and they lost weight. The condition was defined as gastric neurosis.

The diet was to blame. Its physical and chemical properties were harmless to the body. But as an excitor it generated interoceptive impulses that led to grave disorders of stomach secretion. Several days after the sugar and honey diet was terminated digestion became normal. The sugar and honey were inadequate food excitors.

This shed light on one of the causes of gastric neurosis. The research by Bykov and his associates amended the existing theory of neuroses.

NEW WAY

NOT ALL HOSPITALS AND CLINICS apply the treatment founded on Pavlov's teaching. But there is every reason to assert that the research of Soviet physiologists points to a new way of treating many ailments.

An engineer once came to a Leningrad clinic. His high blood pressure, and certain other symptoms, made diagnosing easy. The patient had hypertension.

There are several methods of treating it. One of them involves high-frequency currents. It brought relief to the engineer. The tension in the blood vessels dropped. That was the effect of treatment on the first, and on the following nine days. The same effect was also observed on the eleventh day. And that was the most surprising thing of all, because no currents were applied that day. The circumstances were the same as on the previous ten days, except the electricity. The doctor only snapped the switch, but there was no current in the apparatus. It had been disconnected. In spite of that the tonus, the tension in the blood vessels, dropped, as though the current had passed through them and had done its work.

The affair is easily explained. The snapping of the switch was a conditioned excitor which accompanied the application of high-frequency currents ten times running. The eleventh time the sound alone helped to treat the ailment. It was the effect of a conditioned reflex. But there is one aspect to it that can apply only to human beings.

Why did the engineer's blood pressure drop at the sound of the switch? It was because the patient was certain that the current had been turned on. This certainty reinforced the conditioned reflex. But why was the engineer so sure that the current was there? He had been made to believe it. The environment, and the doctor's words, "I've turned it on," had suggested it.

Suggestion as an excitor in conditioned reflexes may have both negative and positive consequences. Skilful suggestion is capable of a healing effect.

Many complaints, and the role of suggestion in the doctor's therapeutic arsenal, appear in a new light after this. We do not mean the mysterious manipulations and monotonous movements, or passes, in a semi-dark room, which induce sleepiness. What we mean are acts to combat established conditioned reflexes that derange normal processes in the organs and tissues. Patients' complaints, however strange they may seem, are often true, and reflect impulses to the cortex from diseased internal organs.

Whenever the doctor says: "There's nothing really wrong with you; you'll soon be up and about," and supports his words with an appropriate smile, and his general behaviour, he makes the patient believe him. That has a healing effect. The relationship of doctor to patient appears in a new light after the research of Pavlov's followers. The doctor must regard his attitude to the patient, his way of dealing with him, as part of the cure. He must know how to treat the patient, how to speak and to question him, and how to win his confidence, for that is an important factor in the success of his treatment, in rousing the patient's strength to battle the disease. The doctor must turn a mentally depressed and frustrated patient into an optimist. The old adage about a sound mind in a sound body should, as Professor Nagorny aptly put it, be supplemented by its derivative: a sound mind makes a body sound.

It is to be presumed that in certain serious cases of strange, inexplicable, and ruinous psycho-neuroses it is even warranted to resort to hypnosis. The problem of hypnotic treatment appears in a new light today.

PROMISING METHOD

THE PAVLOVIAN SCHOOL has laid a sound foundation for a new method of fighting diseases by protecting the cells of brain centres from anomalous irritations that derange their activity.

Such protection is quite possible. Remember what Pavlov said about protective inhibition. Inhibition protects the brain cells from excessive and unusual excitation. It may, consequently, arrest, or prevent morbid impulses.

Sleep is inhibition. Pavlov's followers suggest the road pioneered by the great scientist—long and deep artificially induced sleep. This principally applies to diseases visibly associated with the nervous factor.

Professor Andreyev applied the sleep cure to 400 ulcer patients. The results were brilliant: 360 cases showed a marked improvement. Many of them were completely cured. But this is not particularly surprising, because the origin of ulcers is unquestionably linked with disorders in the cerebral cortex.

Hypertension, which is attended by high blood pressure, is an extremely serious ailment. Today it is successfully treated with sleep. That again is explained by the fact that hypertension is caused by derangements in the regulating function of the cortical brain centres.

Professor A. A. Vishnevsky's patients underwent sleep cures before and after operations for fractures of the shin bone, hip, shoulder, and forearm. The results were encouraging. Prolonged sleep also aided in the healing of burns, trophic ulcers, inflammations, and many other complaints.

Yet that is only the beginning. There is no doubt that a deeper study and broader application of the new method will contribute generously to the further progress of medicine.

RESULTS OF GROWTH

THE TEACHING OF PAVLOV and the works of his pupils and followers leave no doubt whatsoever that all processes in a living organism are subject to the ceaseless influence and control of the nervous system. The question is, how to explain the all-embracing and decisive role of the nervous system, and particularly of its higher departments, such as the cerebral cortex? For what reason must the nervous system necessarily participate as a principal factor in all the physiological and pathological functions of the body?

Let us turn for an explanation to the history of the evolution of living nature.

The foremost faculty of every living organism is to respond to irritations, to react to changes in the environment. Without that the organism cannot exist.

The simpler the organism and the more primitive its nervous system, the greater the faculty of its other organs to respond directly to irritations. Animals with the least differentiated organs and tissues react with any of their tissues, whatever the irritation. Their bodies have no need of any intermediaries, of any special physiological mechanism, of a specific nervous system. On the lowest rungs of life organisms have no such organ as the nervous system.

The nervous system in its most primitive form appeared as the animal world progressed from its lowest to higher forms. Its development kept pace with the development of new, complex living beings. And its part as an organ receiving the influences of the outer world grew accordingly.

There was another attendant process: other tissues and organs lost their faculty of reacting directly to irritations.

In man, who stands on the highest rung in the animal world as a result of millions of years of historical development, the differentiation of the nervous system from the other physiological systems and tissues incapable of directly responding to irritations, is most pronounced. The nervous system has undertaken the entire task of connecting the outer world and the inner medium. It is the nervous system that reacts to all irritations and adjusts the functions of organs and tissues through the reflex mechanism, which co-ordinates and organizes them in accordance with existing circumstances. Every reaction of the tissues, organs and parts of the body necessarily involves the nervous system. It is this that constitutes, and sustains, the unity of the body.

Pavlov qualified this status of the nervous system, its role, significance, and origin, in the following words: "The more perfect the nervous system of an animal organism, the more it is centralized, and the more and to an ever-increasing degree is its highest part the regulator and distributor of the entire activity of the organism, though this is by no means clearly and manifestly apparent."

This all-embracing significance of the nervous system was shaped in the process of the historical development of living nature. Its part in the inception and development of diseases is great for the same reason. Disease, after all, is the reaction of an organism to a harmful pathogenic influence. The reaction of the body is in the main evoked by that of the nerve tissue.

The Institute of General and Experimental Pathology performed experiments on mice. Mice are born under-developed. It is only on the fifteenth day that their principal physiological systems are fully formed, and that they are in a state of complete functional readiness.

Tetanus toxin was introduced into such new-born, underdeveloped mice. It would appear that death of tetanus was inevitable for these helpless, blind animals that could not as yet hold themselves on their weak little legs. The dose of toxin would have rapidly killed a full-grown animal. But the new-born mice survived. Apart from local changes at the place of the injection, they suffered no ill effects.

There is only one explanation for that: a new-born mouse is still unable to respond with a typical reaction to even so strong an irritant as tetanus toxin. Its interoceptors are in an almost embryonic state. Only after fifteen days, when its nervous system is fully formed, this faculty appears. In a fifteen-day-old mouse an injection of tetanus toxin calls up the usual condition with all its attendant phenomena.

The experiment stresses the significance of the nervous system in both a sound and diseased body. Pavlov put it very aptly: "The nervous system is not only the conductor of all normal physiological processes, but of morbid, pathological processes as well."

* * *

Let us now abandon the laboratories, clinics, and hospitals for the wide-open expanses of life, and look at man in the world that surrounds him.

From the standpoint of the principal propositions based upon the materialistic foundation of the teaching of Sechenov and Pavlov, the outer world not only shapes and develops the mind, but also creates conditions through the cerebral cortex that give rise to diseases of the internal organs, or prevent such diseases. It may be assumed on fully scientific grounds that the conditions of the outer medium also account for many of the internal diseases whose origin and causes are as yet unknown.

CONCLUSION

CHANGING TIMES

DISEASES AND DOCTORS existed at all times. There were eminent physicians hundreds and even thousands of years ago, men who ardently sought to relieve human suffering. They made fortunate observations and discoveries that remain uncontested in many respects to this day.

Two and a half thousand years ago Hippocrates, the greatest physician of ancient Greece, applied cupping glasses, compresses, and hydrotherapy, and made use of skeletal traction and fixed dressings in arm and leg fractures.

A Roman, Celcus, who lived in the day of Nero, was conversant with many sciences, including medicine. He applied poultices and warm dressings, and treated consumption with a generous diet and mountain air, much as its incipient stages are treated today. In the second century Galen taught to distinguish the sick from the sound by their pulse.

In the 16th century Ambroise Paré amputated arms and legs, and ligated arteries and veins in his operations. He applied balsam dressings, which were much like the modern ointment dressings, in gunshot wounds. Paracelsus, who was Paré's contemporary, introduced preparations of iron, zinc, and copper.

But all these discoveries were only the first steps of science. Physicians did not as yet have a comprehensive idea of the structure of the human body, and were ignorant of the functions of its tissues and organs. They did not know what took place in the diseased body, and knew even less of the causes of disease. There were no microscopes, no laboratories, none of the complicated equipment of the modern age, and none of the instruments and devices for examining patients. Physicians had to act blindly. It was chiefly a matter of guesswork, of suppositions that were often mystical, and at best nothing more than accurate descriptions of morbid symptoms. The art of healing was often superceded by quackery and charlatanry. The few available facts could hardly be utilized for therapeutic purposes because they were not properly understood in their relation to each other. Galen, for instance, benefited little from his discovery of the pulse, because he had no idea of its connection with the heart and blood circulation, or of what caused it.

It was only in the 19th century that medicine matured into a genuine science of diseases and of the means to fight them.

THE BACKBONE

IN 1808 THE FRENCHMAN Jean Nicolas Corvisart introduced the practice of percussion, first suggested in 1761. This was a method of determining the condition of internal organs by the sound obtained. In 1819 another Frenchman, Laennec, who was Corvisart's pupil, proposed to investigate the heart and lungs with the aid of auscultation. He invented the stethoscope, which gradually won general recognition. The two remarkable discoveries were at one time known as the "compasses of medicine," and laid the foundation of a new era in diagnostics.

The eminent research of a number of scientists, and notably Claude Bernard, Pirogov, Lister, Pavlov, Botkin, Sechenov, Pasteur, Koch, Mechnikov, Roentgen, and others, revealed the purposes of the various organs, and the role of germs in the origin of diseases. Pavlov's work had a particularly great bearing on the development of the principal departments of the science of sound and diseased bodies. It shed light on the functions of the circulatory and gastrointestinal organs, and first determined the laws governing the cerebral cortex, the laws of the higher nervous activity of human beings. The secrets of the structure and functions of the human body were gradually revealed.

In the latter half of the 19th century the discovery of the part played by germs laid bare the cause of a great many diseases, and facilitated the quest for effective methods of combating them. Anaesthesia was a boon to mankind. Antiseptics and asepsis lent impetus to the development of surgery. Roentgen and radium rays were notable contributions ot diagnostics and therapy. The study of hormones—the substances secreted by endocrine glands—helped to fight diseases previously incurable. The discovery of vitamins and their part in the activity of the body was of the greatest importance.

Modern medicine makes extensive use of technical achievements. Today the physician examines the respiratory tract almost up to the lungs with the aid of the bronchoscope, an instrument equipped with a tiny electric bulb. The oesophagoscope permits examinations of the gullet up to the stomach, and the gastroscope helps to inspect the interior of the stomach itself. There are many other remarkable instruments, quite a few of them designed by Soviet scientists and designers. Today the doctor can see what takes place in a diseased stomach or respiratory tract, the large intestines or the bladder. He can accurately diagnose the patient's complaint, and determine the treatment.

The electron microscope and the perfection of the compound microscope rendered visible the minutest particulars of tissues and cells, and the smallest of disease-carrying agents. The progress of science and engineering yielded new, highly-effective medicines, vaccines, serums, sulfa drugs, vitamins, blood transfusion, and antibiotics. Laboratory investigation techniques are nearly perfect.

The physician of old had nothing of the kind to help him in his work.

The basic criterion of medical progress is the relative number of recoveries. The better the methods of investigation and cure, the more patients recover, the greater the percentage of successes, provided this is not impeded by social, economic, political, and cultural conditions. The number of recoveries determines the level of medicine, its successes, and its scientific and practical worth.

In the days of Hippocrates, Galen, Paré, and up to the 19th century, only a few survived in serious ailments; they were principally those who had strong constitutions and were able to recover without any treatment, sometimes in spite of the treatment, which often did more harm than good.

The rising percentage of recoveries kept pace with the progress of medicine. The closer it approached the 20th century, the greater it became.

Epidemics of the plague, cholera, typhus, typhoid, and small-pox were gradually eliminated—outside the colonial and semi-colonial countries.

In our day decades and even years are enough to measure increases in the percentage of recoveries. Forty years ago, for instance, nine of every ten cases of perforating gastric ulcer ended in death. Today the score is reversed. Only one dies of every ten, thanks to X-rays, blood transfusion, infiltrating novocain anaesthesia, and other factors. About fifteen years ago pernicious anaemia was inevitably fatal. Today treatment is attended by one hundred per cent recovery. But on one condition: the patient must have the means to pay for the treatment and for the necessary medicines.

Meanwhile, the working people in some capitalist countries are not always able to pay for either the treatment, or the drugs.

In the Soviet Union every patient enjoys the benefits of modern medical science, of free medical care, and free treatment at hospitals and clinics.

Medical science builds upon natural science. The successes of the latter pave the way in many respects to those of medicine. It is only with the help of advanced materialistic natural science that medicine can probe the laws governing the functions of sound and diseased bodies. In the U.S.S.R. natural science proceeds from the progressive scientific theory of dialectical materialism. That is why it is a genuine science.

The successes of Soviet public health are characterized by state promotion of preventive medicine, large-scale prophylactic measures, and a steep rise in the percentage of recoveries.

THE KEYS TO HEALTH

SICKNESS IS NEVER WELCOME. The prospect of a relatively speedy cure does not make it less undesirable.

Soviet medicine aims at preventing diseases. It proceeds from the basic principle that "prevention is better than cure."

Germs do not always cause disease. There must be reasons for a man to fall sick. These reasons are living conditions, under-nourishment and an improper diet, exhaustion, a lack of warm clothes, dirt, and an unfit body. They make the body susceptible to illness, and may be in the main attributed to bad socio-economic conditions. Unfit conditions lead to a rising disease incidence.

In the Soviet Union living conditions are on a steady upgrade. That is why disease incidence is dropping. Mortality is dropping too, while the life expectancy and the birth rate, have increased. This is due to the fact that in the Soviet Union the welfare of the working man is a basic state principle. There are not, and cannot be, exploitation of man by man, or crises and unemployment. The Constitution of the U.S.S.R. guarantees its citizens health protection and medical aid. Numerous medical institutions, out-patient clinics, crèches, kindergartens, and mother and child care institutions stand on guard over the health of Soviet people. An extensive network of sanatoriums, health resorts, and holiday homes provides for their vacations. Nation-wide physical culture and sports contribute to the stamina and health of Soviet citizens.

But there are still many unconquered diseases, such as cancer, certain infectious and heart diseases, shock, ulcers, etc. In the 20th century they are being treated much more effectively, of course, than in the 1st, 5th or 16th centuries, and today more effectively than ten or fifteen years ago. But complete success is still somewhat distant.

Scientists, therefore, confront tasks entailing a tremendous creative effort, and great perseverance.

In an address meant for young people, Pavlov said: "Remember that science requires all of a man's life. And if you had two lives they would not suffice either. Science demands great single-mindedness and a great passion."

The Soviet Government offers the scientist extremely favourable conditions for his work, and that has borne its fruits.

A profound study of the human body has placed in our hands the keys to the most delicate processes in the body, the tissues, and the cells, keys to the control of physiological laws in the interests of health protection, keys to health.

Practical medicine today has a sound foundation in the materialistic teaching of Pavlov. The idea of "nervism" is taking its place as the leading principle of preventive and therapeutic medicine, and holds the promise of further successes in the fight for man's health. Faithful to Pavlov's remarkable inferences on protective and regenerative inhibition, doctors have advanced considerably in their treatment of ulcers, shock, mental diseases, bronchial asthma, hypertension, and other complaints.

Pavlov's teaching is a formidable weapon, and medicine still has to make full use of it. Medical science must master all the available keys, in order to solve its basic task of increasing the number of recoveries and lowering mortality, i. e., prolonging life.

It is this that constitutes the elixir of life so unsuccessfully sought down the ages by sorcerers, alchemists, inventors, philosophers, and doctors. The elixir of life is not mere drops or drugs. It is medical discoveries. But, we repeat, medical discoveries alone do not solve the problem of health. The conditions in which these discoveries are applied is a most important and decisive factor.

Should a Soviet citizen require urgent help, an ambulance plane swiftly delivers a doctor to the remotest point on the map. That entails no payment. Health protection is a matter of state concern.

COLLECTIVE EFFORT

THERE IS ANOTHER FACTOR that contributes to Soviet scientific progress. It is collective effort.

Every success of a Soviet scientist is regarded as a success of the entire Soviet science. Soviet scientists achieve results no single man, however gifted he may be, could achieve. They do it with the help of their followers, assistants, and collaborators.

This is best illustrated by Pavlov's example. His discoveries in the sphere of digestion won him world-wide recognition. What he achieved would have been more than enough for the lifetime of several scientists. But besides that, Pavlov also founded the teaching on the function of the cerebral hemispheres—a new teaching on the physiological laws governing the higher nervous activity of animals and men. But in spite of his extraordinary qualities as a research scientist, he would never have done as much as he did if it had not been for the aid of his numerous pupils, who later developed into first-class scientists. Pavlov's pupils are to be met at virtually all scientific centres in the Soviet Union, where they are elaborating on the ideas of their teacher.

It should also be noted that in his creative quest Pavlov drew upon the findings of his predecessors—Sechenov, Botkin, and Vvedensky.

This attitude towards past achievements is another typical trait of Soviet scientists, who build their research upon a firm historical foundation. Pavlov qualified these features of Russian science when receiving the congratulations of the Soviet Physiological Society on his 60th birthday. He said that, firstly, he is the successor of Sechenov, and, secondly, that he does not isolate his work from the work of his associates. "I am glad," he said, "that together with Ivan Mikhailovich (Sechenov), I and the group of my dear collaborators have won for the mighty realm of physiological research the whole and undivided animal organism instead of its vague half. And this is entirely our incontestable Russian contribution to world science, to human thought in general."

What he meant was that the most difficult task was solved and the physiological laws governing the psychic world clearly established. The cerebrum is an organ subject to physiological laws just as any other organ of the body. The entire body without exception, both its somatic and psychic functions, have become tangible objects of physiological research. And Pavlov shared the honour of proving it with all the men and women who worked with him. That was because he viewed science as a common effort, and not the handiwork of individuals. The features so vividly present in Pavlov, in his method and his gift of organizer, are also true for all Soviet scientists, and have become typical and natural in the socialist epoch. The life stories of Michurin, Lysenko, Zhukovsky, and many other scientists in various branches of science, speak of that.

The collective scientific effort at institutes, laboratories and other research institutions, and the creative connection of the past and present, are distinct traits of Soviet science.

In the U.S.S.R. there is another aspect to science: it is indissolubly linked with practice. Scientific discoveries are taken up by countless workers in any way connected with the branch of science concerned, and undergo tests in practice. Everything that justifies itself is put at the disposal of practicians. It would appear, for instance, that Pavlov's teaching constituted a very special discipline applicable only in physiological laboratories and, perhaps, at neuro-psychiatric clinics. Yet every effort is being made to utilize Pavlov's propositions in the matter of improving sanatoriums, physical culture, and in physiotherapy—electrotherapy, mud cure, thermotherapy, hydrotherapy, etc. Pavlov's teaching also extends to agriculture, particularly animal husbandry, where it helps to raise the productivity of cattle.

On the other hand, contributions made by practicians enrich the achievements of science. The work of Rumyantsev, a village doctor in Rostov Region, may serve as an illustration. He utilized Filatov's teaching and his own practical experience to work out a new method of tissue therapy for a number of grave ailments, and achieved considerable success. Today Rumyantsev's method is used by many medical institutions. It is discussed at medical conferences, studied, and improved. Facts of this kind are numerous.

PRINCIPLES OF VERSATILITY

THE READER MAY BE STRUCK by the variety of methods applicable to a single disease. If it is a case of gastric ulcers, for instance, it may be treated with tissue therapy, a novocain blockade, or a sleep cure. Furthermore, there is the old method of a hunger diet. Does the question of choice ever perplex the doctor? Yes, is makes the doctor think. He must weigh a number of factors—the condition of the heart, the vessels, the nervous system, the general condition, the resistibility of the body, and the patient's living conditions. All this helps him to make his choice. But that does not mean that one method excludes the others. Advanced scientific thought demands versatile therapy, a combined application of all factors liable to have a joint beneficial effect. Versatile therapy seeks to act upon all the departments of a diseased body, on the entire body as a single whole. That necessitates a combination of all the suitable methods to supplant one, however good it may be.

Take shock, for instance. The best treatment for shock must combine anaesthesia, palliatives, warmth, a novocain blockade, and blood transfusion.

The human body is an extremely complex mechanism. A number of physiological systems are active in it. Disease is not an isolated disorder of just one organ. Morbid changes in any part of the body necessarily cause a derangement in other organs and tissues. The morbid effects are only more pronounced in one of the organs.

Similarly, the protective functions of the body may not be brought down to a single mechanism, the phagocytic, for example, or the humoral. A living body, to use the military vocabulary, has many fronts. Each front has its own weapons. That is why there may be different ways of setting in motion its defensive forces—the protective reactions of the body regulated and controlled by the central nervous system. Medicine is gradually discovering these means of defence.

THE ATOM SERVES MAN

THE CONQUEST OF ATOMIC ENERGY is the greatest achievement of human genius. Atomic energy can yield light, drive machines, serve as a source of power to transform nature, and thereby enrich nations and lighten the life of men. The possibilities of utilizing the atom for the good of mankind are, indeed, limitless. Atomic energy must benefit humanity and serve progress instead of war which leads to havoc and destruction.

The energy of the invisible particles of an atom has the faculty of healing many diseases and restoring to normal disordered functions of human organs. It opens new prospects, which come ever nearer as researchers master its secrets. Even today medicine has made substantial gains.

Only two sources of atomic radiation were known previously—the X-ray tube and radium. Both were effective in the fight with illnesses. But their scope was nonetheless limited. They were applicable only in certain diseases—principally malignant tumours and affections of the skin.

In 1934 the outstanding scientist and prominent fighter for peace, Frédéric Joliot-Curie, and his wife, Irene Curie, found a way of obtaining artificial radio-active substances known as isotopes, or atoms of the same element and different atomic weights.

Since 1936 a number of papers appeared, which proved that radio-active isotopes may be applied medically, by introducing them into the body. It also turned out that isotopes possess selective qualities with regard to organs: they concentrate in some, avoid others, or gather in them in negligible quantities. The atoms of radio-active phosphorus, for instance, lodge principally in the bones, atoms of radio-active iodine in the thyroid, and radio-active cobalt—in the skin.

Gathering in tissues radio-active isotopes arrest morbid processes. The organs begin to function normally. Thus, radio-active phosphorus is effective in the treatment of blood diseases. Radio-active iodine is used successfully for thyroid gland disorders, and Basedow's disease, or exophthalmic goiter. Radio-active strontium facilitates bone growth in fractures. Radio-active substances are also applied for diagnosing thyroid gland diseases, and in locating internal tumours.

Ray therapy is gaining prominence in oncology. According to the Moscow Central Roentgeno-Radiological Institute 83 out of 100 cases of skin cancer treated with radio-active cobalt, and 70 of 100 cases of malignant tumour of the larynx, recovered.

Representatives of Soviet medicine described their most interesting work in the field of radiology at the Geneva World Conference on the Peaceful Uses of Atomic Energy in August 1955, which was attended by the leading scientists of 72 countries.

* * *

We have described only some of the highlights of medical science. Many scientists have elaborated problems of immediate interest to practical medicine. They comprise only one group of the army of progressive scientists. Many other prominent researchers made remarkable discoveries in the realm of medical science.

Their work and achievements are material for new books.

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